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The opinions expressed by the authors are their own and do not necessarily reflect the views of the Planning and Development Division of the Fertilizer Corporation of India Ltd.

EDITOR'S NOTE

It has now been decided to publish in *TECHNOLOGY* research papers from scientists and technologists outside FCI Ltd., provided these are:

- (i) original and related to fertilizers,
- (ii) approved by external referees chosen by the Editor, and
- (iii) communicated from reputed institutions, and written by workers with adequate experience.

Papers for publication in *TECHNOLOGY* are therefore welcome. These should be sent in duplicate (complete with illustration and abstracts) to the Editor.

Effect of Inorganic Additives on the Phase Transition (IV \leftrightarrow III) of Ammonium Nitrate

By

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The effect of different inorganic additives on the transition temperature of phase IV \leftrightarrow III of solid ammonium nitrate has been studied by differential thermal analysis. It has been observed that moisture affects the temperature of this transition and that anhydrous silica gel, and nitrate of calcium as well as magnesium could be profitably used to increase this temperature. In the case of ammonium nitrate recrystallized from a solution containing a small amount of Ca and Mg nitrate (2 per cent) this temperature is also shifted to the higher side of 32°C. A probable mechanism of their role in the shift of this transition temperature of ammonium nitrate has been proposed. Furthermore, in the case of double salts of (NH₄)₂ SO₄ and NH₄NO₃ in 1 : 1, 1 : 2 and 1 : 3 molar proportions, this transition is absent.

Solid ammonium nitrate shows several polymorphic changes when heated from a sub-zero temperature (−18°C) up to its melting point (170°C). The transitions which take place at different temperatures are as follows: V \leftrightarrow IV phase at −18°C, IV \leftrightarrow III at 32°C, III \leftrightarrow II at 84°C and II \leftrightarrow I at 125°C. Of these transitions, that of phase IV \leftrightarrow III, which takes place at 32°C, is very prone to cause caking because it is possible only in the presence of moisture and again this transition takes place through a solution and recrystallization process¹. It is believed that the actual temperature of this transition is 55°C which is observed in case of perfectly anhydrous ammonium nitrate and this temperature is lowered continuously up to 32°C by an increasing amount of moisture². The amount of moisture necessary to effect this change is very small and ammonium nitrate with moisture content as low as 0.2 per cent shows a transition at 32°C. Since ammonium nitrate is very hygroscopic in nature and the normal temperature in tropical countries, like India, fluctuates widely around 32°C, caking of ammonium nitrate as well as of the fertilizers containing this compound is very much facilitated in these zones. Therefore, attempts have been made either to eliminate this transition or change its temperature to the higher or lower side. It has been observed that the use of high pressure shifts this transition temperature to the higher

side of 32°C. Proper annealing of solid ammonium nitrate sometimes eliminates this transition³. Use of additives like potassium nitrate has also been found to shift this temperature to the lower side. The lowering of this temperature in this case has been found to be due to substitution of NH₄⁺ by K⁺ ions in the NH₄NO₃ lattice⁴. Compared to the above, the use of calcium and magnesium nitrate has been found to increase this transition temperature, but the role of their different states of aggregation in this transition has not yet been studied. The effect of other additives, like mono-, di- and tri-ammonium phosphates, has also been studied⁸. They are found to be without any effect on this transition.

Again, ammonium nitrate forms double salts with other compounds like ammonium sulphate⁵ and calcium nitrate⁶. The crystal structures of these double salts are believed to be different from that of ammonium nitrate. As such it is likely that the phase IV \leftrightarrow III transition of ammonium nitrate will be affected by this double salt formation.

Keeping these in view, an attempt has been made to study the phase IV \leftrightarrow III transition of ammonium nitrate containing certain inorganic additives, with particular reference to the role of their different states of aggregation in this transformation.

Experimental

The chemicals used were of A.R. grade. All samples used were dried in a desiccator, containing anhydrous silica gel.

Two sets of mixtures were used for this investigation. They were as follows:

1. Ammonium nitrate mechanically mixed with different proportions of ammonium sulphate (0, 5, 10, 15, 30, 45 and 62 per cent), limestone (40 per cent, a composition similar to CAN fertilizer), $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Pb}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Ca}(\text{NO}_3)_2 \cdot 1\frac{1}{2}\text{H}_2\text{O}$ (dehydrated from its $4\text{H}_2\text{O}$ form at a temperature of 110°C for one hour, its composition determined by TGA), $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$ (dehydrated from its $6\text{H}_2\text{O}$ form at 110°C^9), (each 2 per cent calculated as anhydrous salt in case of hydrates), and anhydrous SiO_2 gel (25 per cent).

2. Samples were recrystallized from saturated solutions of NH_4NO_3 and $(\text{NH}_4)_2\text{SO}_4$, $\text{Ca}(\text{NO}_3)_2$, $\text{Mg}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2$ and $\text{Pb}(\text{NO}_3)_2$. The procedure for recrystallization of NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$ from ammonium nitrate solution containing different proportion of ammonium sulphate is reported by Srinivasa et. al⁷. The composition of the recrystallized products were $(\text{NH}_4)_2\text{SO}_4$, NH_4NO_3 in 1 : 1, 1 : 2, and 1 : 3 molar proportions. The crystals from saturated NH_4NO_3 solution, containing Ca, Mg, Zn and Pb nitrate (2 per cent each) were allowed to form over sulphuric acid (conc.) in a vacuum desiccator at a room temperature of about 24°C and were finally dried over anhydrous silica gel in a desiccator before use.

The moisture content of the desiccated ammonium nitrate was determined by a thermogravimetric method. The desiccated sample was taken in a platinum cup kept inside the furnace, whose temperature was raised up to 110°C at a rate of $10^\circ\text{C}/\text{min}$. The temperature was then kept constant for about an hour till the weight loss was found to be constant. The moisture was found to be 0.2 per cent.

The differential thermal analysis of these samples was carried out by a manually operated instrument in the temperature range of 24 to 90°C . The rate of rise of temperature was controlled at about $1^\circ\text{C}/\text{min}$. up to 40°C and about $3^\circ\text{C}/\text{min}$. afterwards. The thermocouples for temperature measurement as well as the differential e.m.f. were chromel/alumel and the temperature of the furnace was measured by means of a previously calibrated pyrometer. Sample holders were made of thin platinum cylinders. The reference substance was $\alpha\text{-Al}_2\text{O}_3$. For dehydrated ammonium nitrate

the sample holder used was a thin platinum cup open at one end only and having a provision for introducing a thermocouple bead at the bottom. The sample was first taken in the cup, dried in the oven at 95°C for an hour and the open end of the cup was closed by a rubber stopper while hot. The whole thing was then cooled in a desiccator and placed on the thermocouple bead for experiment. In case of $\text{Ca}(\text{NO}_3)_2 \cdot 1\frac{1}{2}\text{H}_2\text{O}$ and $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$, their tetra and hexahydrates respectively were taken in this cup, dried at 110°C , for an hour and cooled. The desiccated ammonium nitrate was then added by opening the stopper and replacing it immediately. D.T.A. investigations of these samples are shown in the form of their thermograms (represented in Figs. 1-6).

Discussion

The DTA curve of the desiccated ammonium nitrate (with moisture 0.2 per cent) shows endothermic peaks at 32° and 84°C which are due to the usual transitions of phase $\text{IV} \leftrightarrow \text{III}$ and $\text{III} \leftrightarrow \text{II}$ (Fig. 1). But in the case of the oven dried sample the first peak in its DTA thermogram is shifted to a higher temperature i.e. 41°C . This confirms the earlier report^{1,2} that moisture affects the phase $\text{IV} \leftrightarrow \text{III}$ transition. But a desiccated sample when mixed with limestone (40 per cent) shows no such shift in its DTA diagram (Fig. 2). In contrast to that desiccated ammonium nitrate with 25 per cent admixture of anhydrous SiO_2 gel shows a shift of this transition temperature up to 37°C . This indicates that the SiO_2 gel takes up moisture from the ammonium nitrate.

Again, desiccated ammonium nitrate with 2 per cent admixed $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ and $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ shows no change in the transition temperature of phase $\text{IV} \leftrightarrow \text{III}$ (Figs. 3, 4). But with each of $\text{Ca}(\text{NO}_3)_2 \cdot 1\frac{1}{2}\text{H}_2\text{O}$ and $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$ mixed in same proportion there is a shift in this transition temperature up to

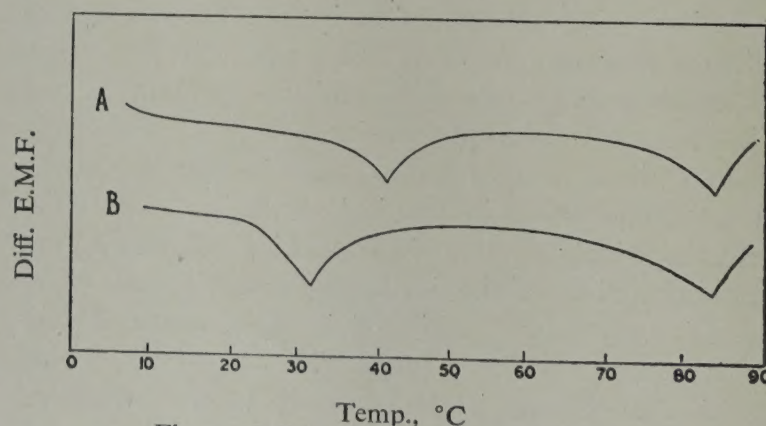


Fig. 1—DTA Thermograms of NH_4NO_3
A—Over Dried
B—Desiccated

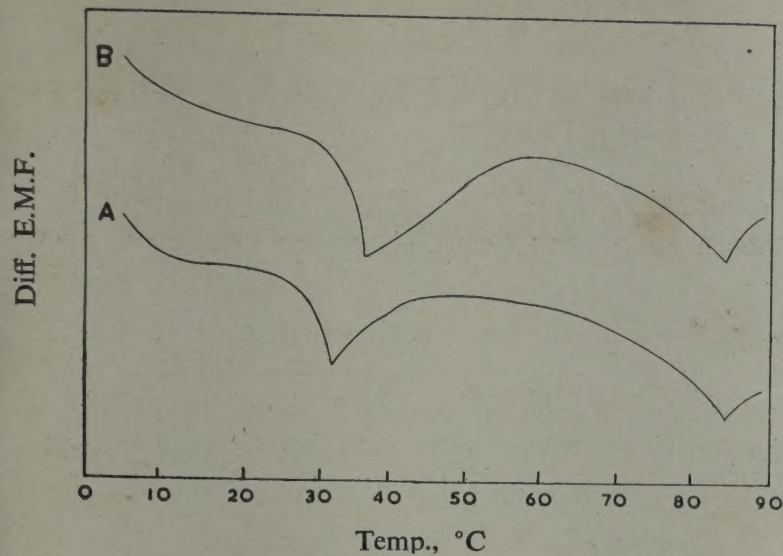


Fig. 2—DTA Thermograms of Mechanically Mixed NH_4NO_3 and Some Additives.
A— NH_4NO_3 + 40% Limestone
B— NH_4NO_3 + 25% Anhydrous Silica Gel

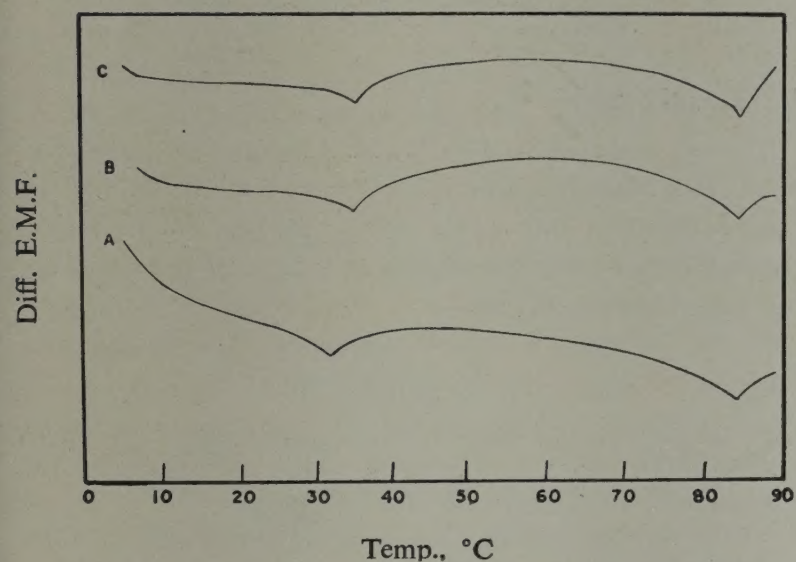


Fig. 3—DTA Thermograms of Mechanically Mixed NH_4NO_3 with $\text{Ca}(\text{NO}_3)_2$ (in Different Hydrated Form) and Their Recrystallized Salt.
A—Mechanical Mixture of NH_4NO_3 + 2% $\text{Ca}(\text{NO}_3)_2 \cdot 4 \text{H}_2\text{O}$
B—-do- but with 2% $\text{Ca}(\text{NO}_3)_2 \cdot 1.1/2 \text{H}_2\text{O}$
C—Recrystallized NH_4NO_3 with 2% $\text{Ca}(\text{NO}_3)_2$

35-38°C. This indicates that they play the same role as that of anhydrous SiO_2 gel and their function will cease when these nitrates are hydrated to their respective tetra and hexa forms and exist as mechanical mixtures with ammonium nitrate having a moisture content sufficient for this transition to occur at 32°C.

Again desiccated ammonium nitrate when mixed with different proportions of ammonium sulphate shows no change in its phase $\text{IV} \leftrightarrow \text{III}$ transition temperature. But in the case of its recrystallized product with ammonium sulphate in 1:1, 2:1 and 3:1 molar proportions, the peak due to the phase $\text{IV} \leftrightarrow \text{III}$

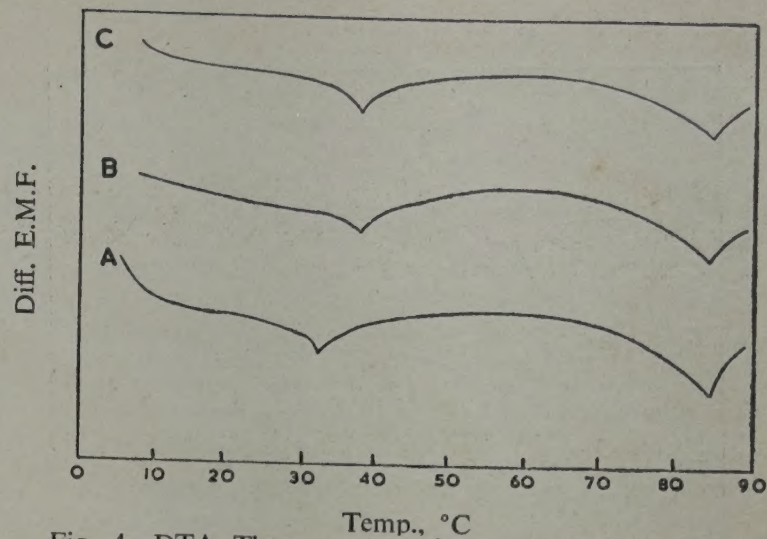


Fig. 4—DTA Thermograms of the Mechanically Mixed NH_4NO_3 with $\text{Mg}(\text{NO}_3)_2$ (in Different Hydrated Form) and Their Recrystallized Salt.
A—Mechanical Mixture of NH_4NO_3 + 2% $\text{Mg}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$
B—-do- but with 2% $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$
C—Recrystallized NH_4NO_3 with 2% $\text{Mg}(\text{NO}_3)_2$

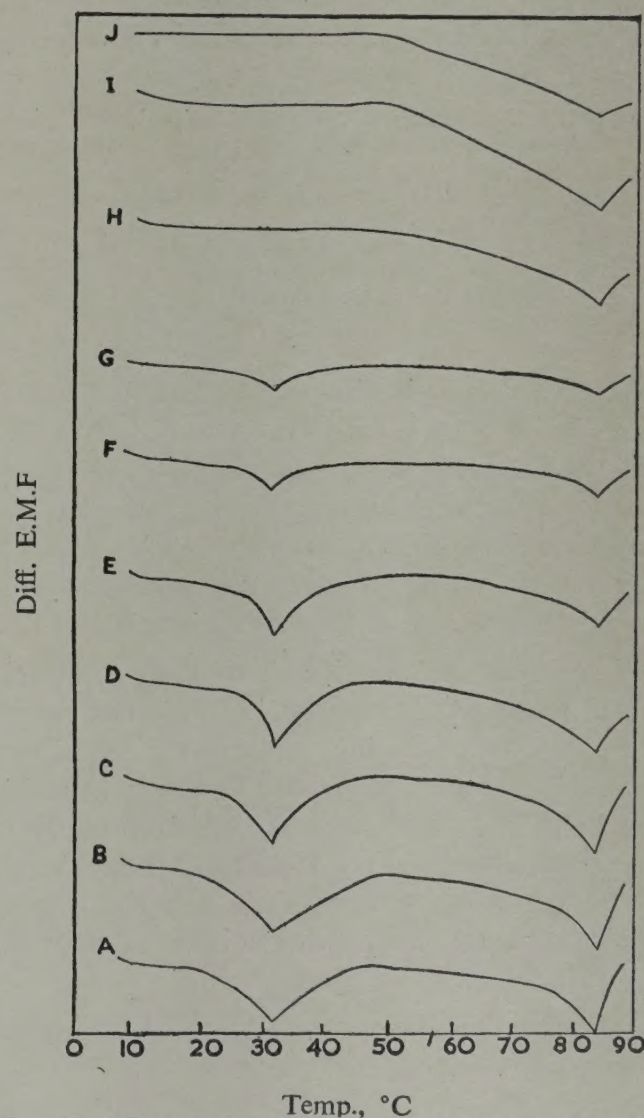


Fig. 5—DTA Thermograms of Mechanically Mixed NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$ and Their Recrystallized Salts, A, B, C, D, E, F, G Mechanical Mixtures of NH_4NO_3 and $(\text{NH}_4)_2\text{SO}_4$ Containing 0, 5, 10, 15, 30, 45, 62 p.c. $(\text{NH}_4)_2\text{SO}_4$ Respectively. H, I and J Their Recrystallized Salts in 1:1, 2:1, and 3:1 Molar Proportions.

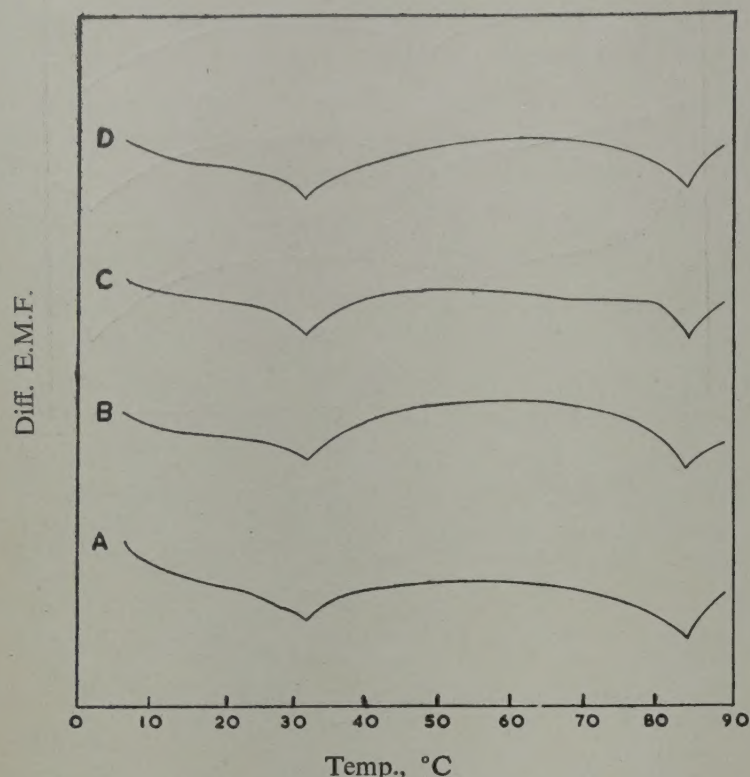


Fig. 6—DTA Thermograms of the Mechanically mixed NH_4NO_3 with $\text{Pb}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and Their Recrystallized salts.
 A—Mechanical mixtures of $\text{NH}_4\text{NO}_3 + 2\% \text{ Pb}(\text{NO}_3)_2$
 B—-do- but with $2\% \text{ Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$
 C—Recrystallized salt of A
 D—Recrystallized salt of B

transition of NH_4NO_3 is absent, whereas that at 84°C is present in each case (Fig. 5). X-ray study reveals that they are double salts of $\text{NH}_4\text{NO}_3 \cdot (\text{NH}_4)_2\text{SO}_4$ type and their crystal structures are different from that of ammonium nitrate⁷. But the peak at 84°C is definitely due to phase III \longleftrightarrow II transition of ammonium nitrate. This indicates that they dissociate below 84°C .

It is interesting to mention here that ammonium nitrate, when recrystallized from its saturated solution containing 2 per cent calcium and magnesium nitrates, shows a similar shift of the phase IV \longleftrightarrow III transition temperature as that of mechanically admixed $\text{Ca}(\text{NO}_3)_2 \cdot 1\frac{1}{2} \text{H}_2\text{O}$, or $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$. The reason for this shift will not be analogous to that of the $\text{NH}_4\text{NO}_3\text{—KNO}_3$ recrystallized system, as the ionic radii of Ca^{2+} and

Mg^{2+} are 1.06 and 0.78 \AA respectively as against that of 1.43 \AA of the NH_4^+ ion. Similar studies with other metal nitrates (Zn^{2+} and Pb^{2+}) of ionic radii 0.83 and 1.32 \AA were made. No such change was observed in the case of their mechanically admixed samples (with 2 per cent additives) or of their recrystallized products from saturated solution (Fig. 6). Hence substitution of Ca^{2+} and Mg^{2+} ions in the NH_4NO_3 lattice is unlikely. Again, ammonium nitrate mechanically mixed with $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ or $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, when desiccated under identical conditions to their recrystallized salt, does not show any shift of this transition temperature. This indicates that the state of aggregation of calcium and magnesium nitrates in the recrystallized salt is different from their respective tetra and hexa hydrates. The shift of this temperature in the recrystallized salt may, therefore, be ascribed to the formation of their double salt with ammonium nitrate.

Acknowledgement

Thanks are due to Dr. K. R. Chakravorty, General Manager, Planning and Development Division, for his keen interest in this work and to Dr. B. K. Banerjee, Deputy Superintendent, Physical Research Department, for his valuable advice.

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Thermal Studies on Ammonium Nitrate Phosphate Systems

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DTA and thermogravimetric analysis of binary mixtures of ammonium nitrate with each of mono and di-ammonium hydrophosphate as well as tri-ammonium phosphate were carried out. It was observed that each of mono- and di-ammonium hydrophosphates forms one eutectic diagram with ammonium nitrate and their eutectic temperatures are 150 and 155°C respectively, which are well below the melting point of ammonium nitrate. The decomposition of the mixtures of their eutectic composition is negligible when heated to 160°C and subsequently cooled rapidly. Unlike these, decomposition of tri-ammonium phosphate is quite appreciable and its phase equilibrium with ammonium nitrate could not, therefore, have been ascertained by the DTA method.

Introduction

A knowledge of the thermal behaviour of binary mixtures of ammonium nitrate and phosphate is of importance for the manufacture of mixed N-P fertilizer by processes such as prilling and graining. It is known that solid ammonium-nitrate shows several polymorphic changes when heated from room temperature up to its melting point at 170°C; the sample decomposes very little before melting but decomposition is very rapid above 200°C and complete at about 260°C¹. Unlike ammonium nitrate, ammonium phosphates decompose slowly on heating and their stability towards heat decreases with the increase of ammonia content. Triammonium phosphate (TAP) loses ammonia even at ordinary temperatures whereas di- and mono-ammonium hydrophosphate (DAP and MAP) do so at higher temperatures². Again MAP melts at 200°C, and is converted to other phosphates with higher P_2O_5 content upon heating for one or two hours at its melting point. Besides this, MAP forms a simple eutectic diagram with ammonium nitrate when their mixtures are heated up to 200°C. The eutectic composition for this system was found to be 86 per cent ammonium nitrate and 14 per cent $NH_4H_2PO_4$, having a eutectic temperature at 148°C³. No compound formation in this system was observed in the solid phase. But very little is known about the thermal behaviour of mixtures of other phosphates with ammonium nitrate.

In the present investigation attempts have, therefore, been made to study the thermal characteristics of binary mixtures of ammonium nitrate and phosphates by differential thermal and thermogravimetric (TGA) analysis.

Experimental

Samples used for this investigation were prepared from A.R. quality ingredients. Different binary mixtures of ammonium nitrate with each of MAP, DAP and TAP were prepared mechanically in powder form by using an agate mortar. All samples were kept in a desiccator overnight before use. Anhydrous silica gel was used as the dehydrating agent in the desiccator.

The differential thermal analysis of these samples was performed in a manually operated apparatus fabricated in this laboratory. The temperature range used was 26–200°C, at which temperatures all samples were found to be either melted or decomposed. The sample holder was made of thin platinum sheet in the form of a cylinder. The thermocouple used for this purpose was chromel-alumel. The rate of rise of temperature was maintained at about 1°C/min. up to 40°C and 10°C/min. afterwards. The temperature of the furnace was recorded by means of a previously calibrated indicator. The accuracy of the observed temperature was $\pm 2.5^\circ\text{C}$. The reference substance used was ignited alumina. The peak due to the melting point

of the system was confirmed by removing the sample holder from the furnace immediately after the appearance of the peak and observing it visually. The melting point of a sample was taken as this peak temperature. DTA curves of ammonium nitrate, the phosphates and their mixtures are shown in Figs. 1, 2 and 3. In Fig. 4 the melting point of the systems, viz. MAP and DAP with NH_4NO_3 , are plotted against composition.

The decomposition of these samples up to 300°C was studied with the thermogravimetric apparatus. A small platinum cup was hung by a thin platinum wire from one pan of a sensitive balance inside a furnace whose temperature was raised uniformly at a rate of 10°C and $5^\circ\text{C}/\text{min.}$ by means of a manually operated variac. TGA curves are shown in Fig. 5. The extent of decomposition of ammonium nitrate, phosphates and their mixtures with ammonium nitrate (40 : 60) at different temperatures and rates of heating is shown in Table 1. The eutectic mixtures were also heated to 160°C by raising the temperature of the furnace at a rate of $10^\circ\text{C}/\text{min.}$ and cooling immediately in a desiccator. X-ray diffraction photographs of these mixtures before and after heating were taken with a Debye Scherrer camera of 11.5 cm. diam. using $\text{CuK}\alpha$ radiation generated at 40 kV and 20 mA in a Philips PW 1010 unit. The X-ray data are given in Tables 2A and 2B.

Discussion

The DTA curve of solid ammonium nitrate (Fig. 1) shows endothermic peaks at $32, 84, 125$ and 170°C . The first three peaks indicate different polymorphic transitions, whereas the last one is due to melting of

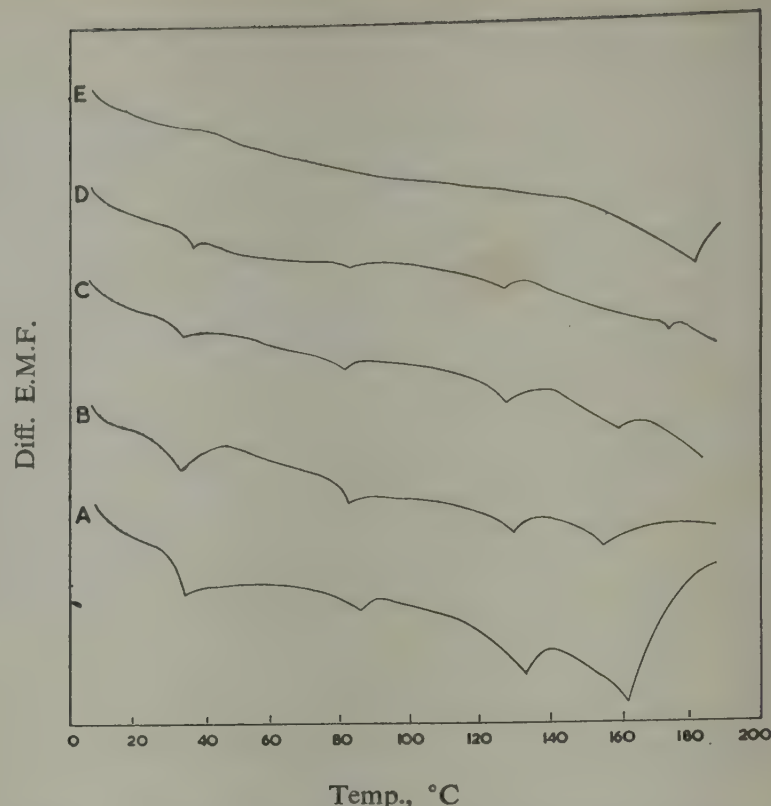


Fig. 2—DTA Thermograms of $\text{NH}_4\text{NO}_3-(\text{NH}_4)_2\text{HPO}_4$ Mixtures. A, B, C, D and E Represent Mixtures Containing 20, 40, 60, 80 and 100 p.c. $(\text{NH}_4)_2\text{HPO}_4$ Respectively.

the sample. It has been observed that these polymorphic transitions of ammonium nitrate are also exhibited in binary mixtures containing MAP and DAP as well as to some extent in TAP (Figs. 1, 2 and 3), and these peak temperatures are practically unaffected by the presence of these phosphates. This indicates that in the solid state, ammonium nitrate does not form a

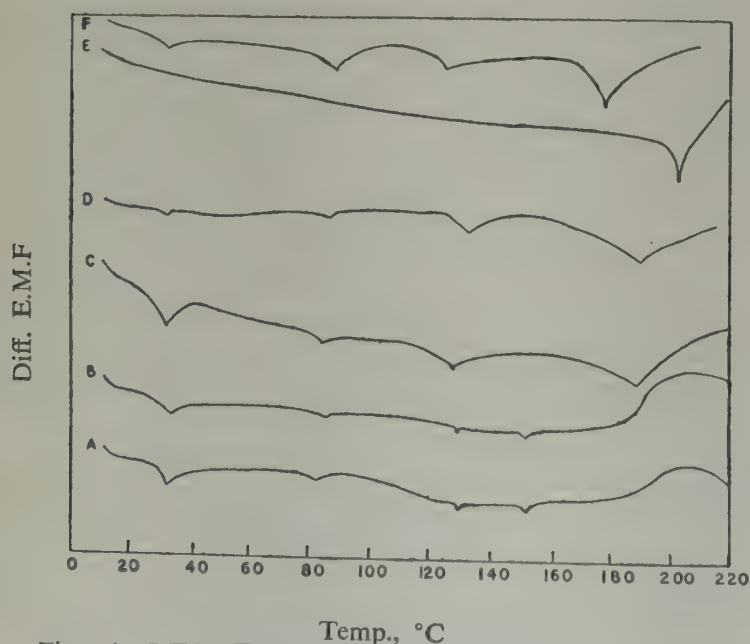


Fig. 1—DTA Thermograms of $\text{NH}_4\text{NO}_3-\text{NH}_4\text{H}_2\text{PO}_4$ Mixtures. A, B, C, D and E represent Mixtures Containing 10, 20, 50, 80 and 100 p.c. $\text{NH}_4\text{H}_2\text{PO}_4$ Respectively. F Represents 100 p.c. NH_4NO_3

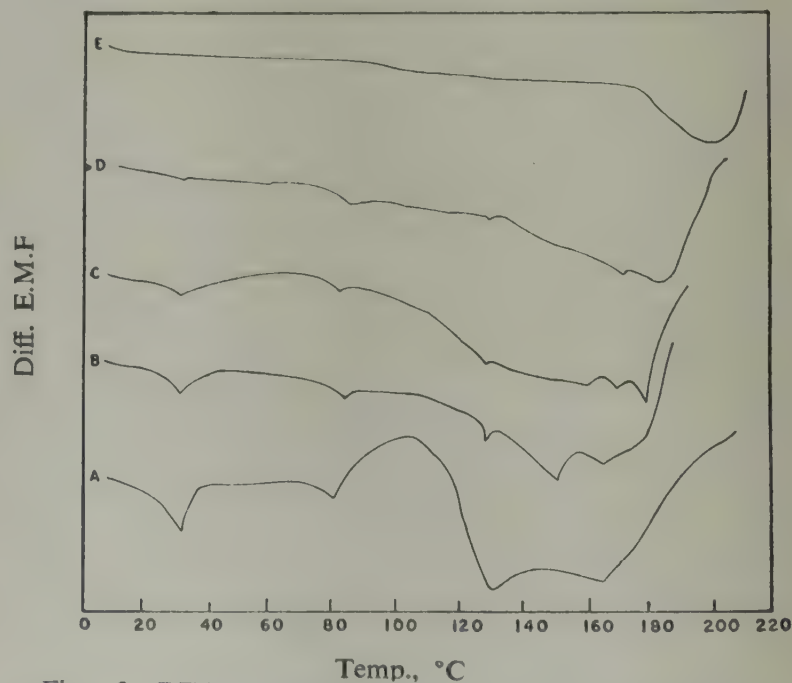


Fig. 3—DTA Thermograms of $\text{NH}_4\text{NO}_3-(\text{NH}_4)_3\text{PO}_4$ Mixtures, A, B, C, D and E Represent Mixtures Containing 20, 40, 60, 80 and 100 p.c. $(\text{NH}_4)_3\text{PO}_4$ Respectively.

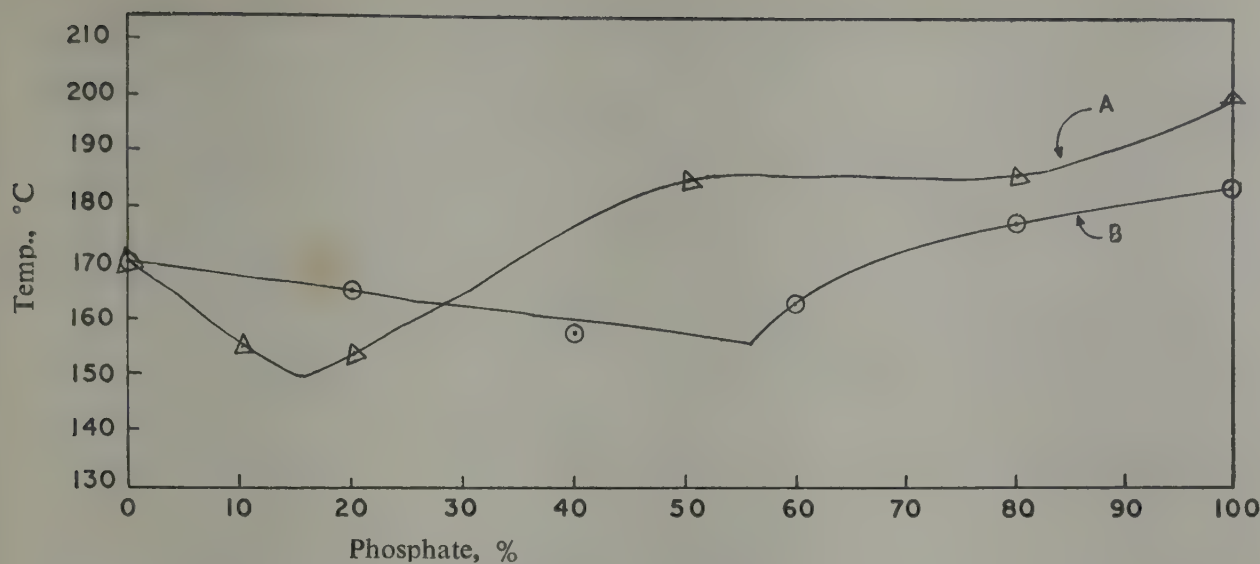
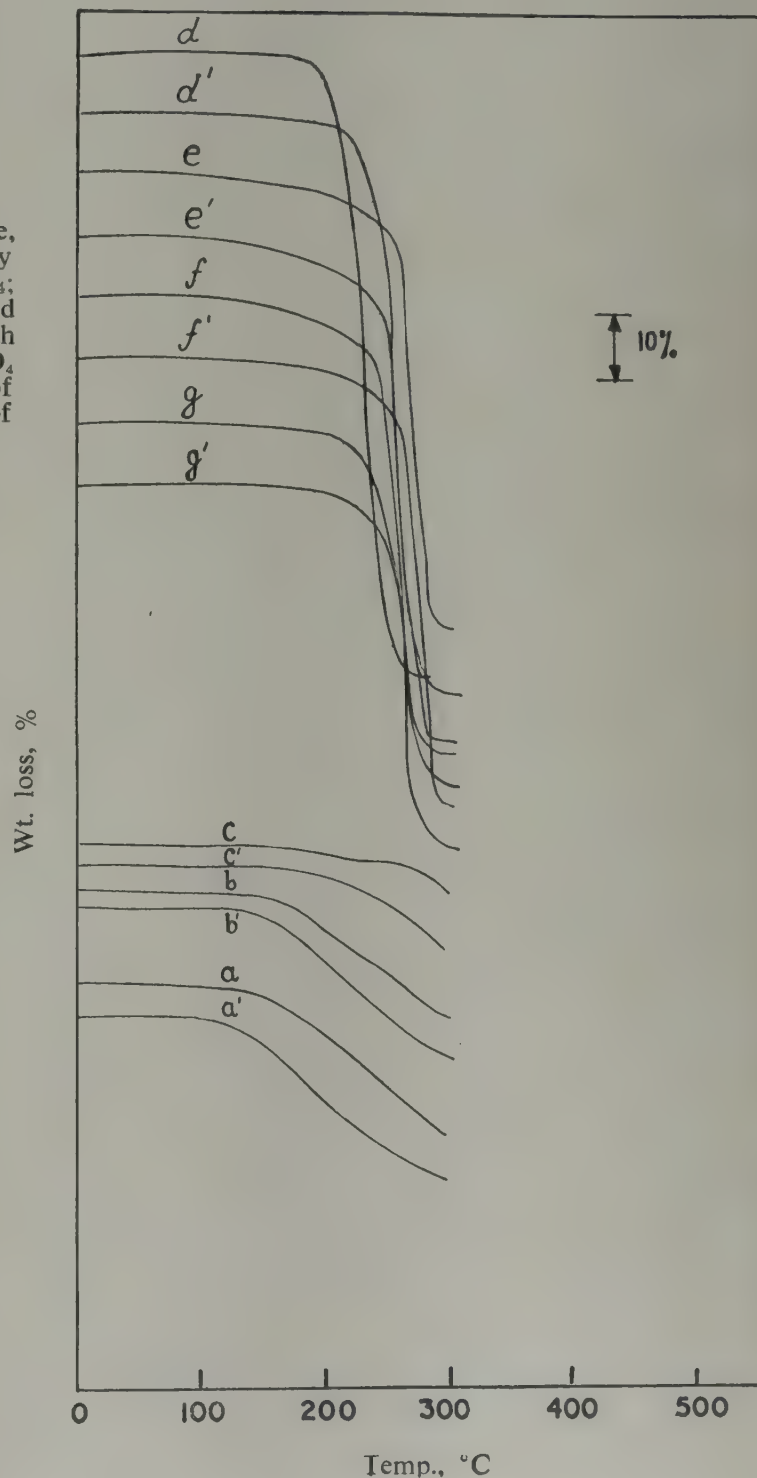


Fig. 4—Melting Point vs. Composition of NH_4NO_3 -Ammonium Phosphates Mixtures.
A— NH_4NO_3 - $\text{NH}_4\text{H}_2\text{PO}_4$;
B— NH_4NO_3 -(NH_4) $_2\text{HPO}_4$

Fig. 5—Thermogravimetric Curves of Ammonium Nitrate, Ammonium Phosphates and Their Binary Mixtures a,a'-(NH_4) $_3\text{PO}_4$; b,b'-(NH_4) $_2\text{HPO}_4$; c,c'- $\text{NH}_4\text{H}_2\text{PO}_4$; d,d'- NH_4NO_3 , e,e'; f,f'; and g,g' Represent 60:40 Mixtures of NH_4NO_3 with each of (NH_4) $_3\text{PO}_4$, (NH_4) $_2\text{HPO}_4$ and $\text{NH}_4\text{H}_2\text{PO}_4$ Respectively. a.....g Represent Heating Rate of 10°C/min. a'.....g' Represent Heating Rate of 5°C/Min.

compound with any of them. But the temperature of the peak due to melting of their mixtures varies with the composition of the system containing MAP and DAP (Fig. 4). In each binary system the melting temperature decreases initially below that of pure ammonium nitrate with increase of the proportion of phosphate till the eutectic point is reached after which it again rises. In the case of the ammonium nitrate—MAP system, such a eutectic corresponds to the composition of 85 per cent ammonium nitrate and 15 per cent MAP and its eutectic temperature has been found to be 150°C. This value is in good agreement with that on the eutectic diagram obtained by Bergman et al⁴. In the case of the ammonium nitrate—DAP system such a eutectic occurs at 44 per cent ammonium nitrate and 56 per cent DAP with its melting temperature at 155°C. In the case of the ammonium nitrate and TAP mixtures no such relation could be obtained. Unlike in the other systems, their DTA curves show multiple endothermic peaks in the region of 140-200°C. (Fig. 3). These may be due to decomposition of the TAP during heating and melting of the products formed. In fact TGA analysis shows that the extent of its decomposition is much greater than that of MAP and DAP in this temperature range (Fig. 5).



Again the extent of decomposition of ammonium nitrate, ammonium phosphates, and their (60 : 40) mixtures decreases with increase of heating rate (Table 1). This indicates that the use of a sufficiently high rate of heating reduces such undesirable decomposition considerably. Using a heating rate of 10°C/min., the mixtures of their eutectic composition were heated up to 160°C and cooled rapidly. X-ray data (Tables 2A and 2B) of such mixtures reveal that the composition of these heated samples are practically similar to those of their respective unheated components.

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TABLE 1—DECOMPOSITION OF AMMONIUM NITRATE, AMMONIUM PHOSPHATES AND THEIR BINARY MIXTURES AT DIFFERENT TEMPERATURES AND RATES OF HEATING

Sample	Decomposition, %					
	At 5°C/min. (Heating Rate)			10°C/min. (Heating Rate)		
	150°C	180°C	200°C	150°C	180°C	200°C
Ammonium Nitrate	0.2	0.4	0.8	0.2	0.3	0.4
Mono-Ammonium Phosphate (MAP)	0.2	1.6	2.2	0.1	0.3	1.0
Di-Ammonium Phosphate (DAP)	1.6	5.3	7.5	0.8	3.0	5.5
Tri-Ammonium Phosphate (TAP)	5.0	10.1	13.5	2.9	4.8	8.5
NH ₄ NO ₃ +MAP 60% 40%	0.2	0.5	0.9	0.1	0.3	0.5
NH ₄ NO ₃ +DAP 60% 40%	0.8	1.3	2.8	0.4	1.1	2.1
NH ₄ NO ₃ +TAP 60% 40%	2.5	3.1	5.7	1.7	2.6	5.0

TABLE 2A—X-RAY DATA OF NH₄NO₃-NH₄H₂PO₄ EUTECTIC MIXTURE BEFORE & AFTER HEATING TO 160°C

NH ₄ NO ₃ : NH ₄ H ₂ PO ₄ (85 : 15 Mixture)				Standard* X-ray Data			
Unheated		Heated to 160°C		NH ₄ NO ₃ (phase-IV)		NH ₄ H ₂ PO ₄	
I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)
ms	5.32	s	5.33			s	5.30
w	4.90	w	4.91	m	4.90		
vw	4.15	vw	4.18				
ms	3.93	ms	3.91	ms	3.93		
w	3.76	ms	3.76			ms	3.73
ms	3.41	ms	3.40				
vs	3.07	vs	3.08	s	3.08	vs	3.08
vw	2.87	vw	2.84	w	2.87		
ms	2.72	w	2.73	ms	2.71		
vw	2.65	vw	2.66			m	2.65
ms	2.49	ms	2.49	ms	2.48		
vw	2.45	vw	2.45				
w	2.38	w	2.37	w	2.37	w	2.38
ms	2.25	ms	2.26	m	2.25		
vw	2.16	vw	2.22			vw	2.16
w	2.005	w	2.009			ms	2.005
vw	1.977	vw	1.980	w	1.973		
vw	1.789	vw	1.786	w	1.783		
vw	1.632	vw	1.632	w	1.628		
vw	1.599	vw	1.60			w	1.60
vw	1.512	vw	1.510	w	1.511		
vw	1.491	vw	1.490	w	1.490		

* V. Sauchelli, *Chemistry and Technology of Fertilizers*, (Reinhold Publ. Corpn., N. Y.), 1960.

I—Relative intensity; d—interlayer spacing; vs—very strong; ms—medium strong; m—medium; w—weak; vw—very weak.

TABLE 2B—X-RAY DATA OF NH_4NO_3 -(NH_4) $_2\text{HPO}_4$ EUTECTIC MIXTURE BEFORE AND AFTER HEATING UPTO 160°C

NH_4NO_3 : (NH_4) $_2\text{HPO}_4$ (44 : 56) Mixture				Standard* X-ray Data			
Unheated		Heated to 160°C		NH_4NO_3 (phase-IV)		$(\text{NH}_4)_2\text{HPO}_4$	
I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)
ms	5.60	w	5.59			s	5.60
ms	5.32	ms	5.33			w	5.30
ms	5.01	ms	5.01			vs	5.05
w	4.16	w	4.13			m	4.11
s	3.95	ms	3.91	ms	3.93	w	3.99
s	3.78	s	3.75			ms	3.78
w	3.42	ms	3.40			w	3.42
w	3.21	w	3.21			s	3.21
vs	3.07	vs	3.07	s	3.08	s	3.04
vw	2.88	vw	2.89	w	2.87		
w	2.81	w	2.82			ms	2.81
ms	2.72	ms	2.72	ms	2.71		
ms	2.65	ms	2.64			m	2.54
ms	2.54	w	2.54			w	2.46
w	2.48	w	2.47	m	2.47	w	2.43
w	2.43	w	2.41				
w	2.38	w	2.37	ms	2.37		
ms	2.26	ms	2.26	ms	2.25	w	2.26
s	2.01	s	2.005	w	2.08	w	2.02
vw	1.917	vw	1.915			w	1.915
vw	1.83	vw	1.82	w	1.83	vw	1.83
w	1.77	ms	1.77	w	1.78		
vw	1.740	vw	1.739			vw	1.740
vw	1.63	vw	1.63	w	1.628	vw	1.630
w	1.60	w	1.60	w	1.57		
vw	1.51	vw	1.51	w	1.51	vw	1.50
vw	1.495	vw	1.494	w	1.490		
w	1.472	w	1.472	w	1.46		

* V. Sauchelli, *Chemistry and Technology of Fertilizers*, (Reinhold Publ. Corp., N. Y.), 1960.

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Optimization of Cobalt-Molybdate Type of Catalyst for Hydrodesulphurization of Petroleum Feedstocks—Part I

By

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Ethyl mercaptan was hydrogenated in presence of nickel promoted cobalt-molybdate catalyst having cobalt oxide, molybdic oxide and nickel oxide as active components. In the four sample tests carried out in the present investigation, the active components of the catalysts were varied according to the statistical optimization procedure put forward by Box and Wilson. Effect per unit of different active components were established and based on this several best paths were selected. Trials on some of the best paths are in progress to find the optimum composition of the catalyst.

Introduction

Recently cobalt-molybdate catalysts on alumina carriers have been widely used by different workers²⁻¹⁶ for study on hydrodesulphurization of petroleum feedstock. Most of the workers²⁻⁹ have used catalysts with CoO concentration between 2-4.4 per cent by wt and CoO/MoO₃ molar ratio between 0.65-1.0. A section of workers¹⁰⁻¹³ have used catalysts with CoO concentration between 1.80-2.54 per cent by wt and CoO/MoO₃ molar ratio between 0.20-0.44; One reference¹⁴ shows catalysts with CoO as high as 7.8 per cent by wt and CoO/MoO₃ molar ratio as high as 2.08, while another reference¹⁵ gives as wide a range of composition as 1-20 per cent by wt CoO and 2-25 per cent by wt MoO₃ and rest Al₂O₃. There has been, however, only one publication as to what might be the optimum composition of alumina supported cobalt molybdate type of catalyst. It is the purpose of the present paper to investigate into the effect of composition on the activity of alumina supported and nickel promoted cobalt molybdate type of catalyst so as to get an optimum composition of the catalyst for hydrodesulphurization of petroleum hydrocarbons.

Optimizations Procedure

Based on statistical optimization procedure by Box and Wilson¹, Li¹⁷ has given a worksheet for finding the optimum conditions of the variables affecting a multivariant desired objective. The basis of the worksheet is as follows: Preliminary choice of base levels of variables and their unit values are made on the basis of available information regarding the effect of these variables on the desired objective. Addition or subtraction of these unit values to or from the base levels determines the high and low levels. Now if there are n variables (n must be an odd number for the application of this procedure), $n+1$ sample tests are to be made by taking high and low levels of these variables in such a fashion that if the sum total of individual levels for a particular set of $\frac{n+1}{2}$ tests are subtracted from those for the remaining $\frac{n+1}{2}$ tests, all the individual levels would vanish except one which would show a value equal to $(n+1)$ times the unit value of the particular variable concerned. The effect per unit

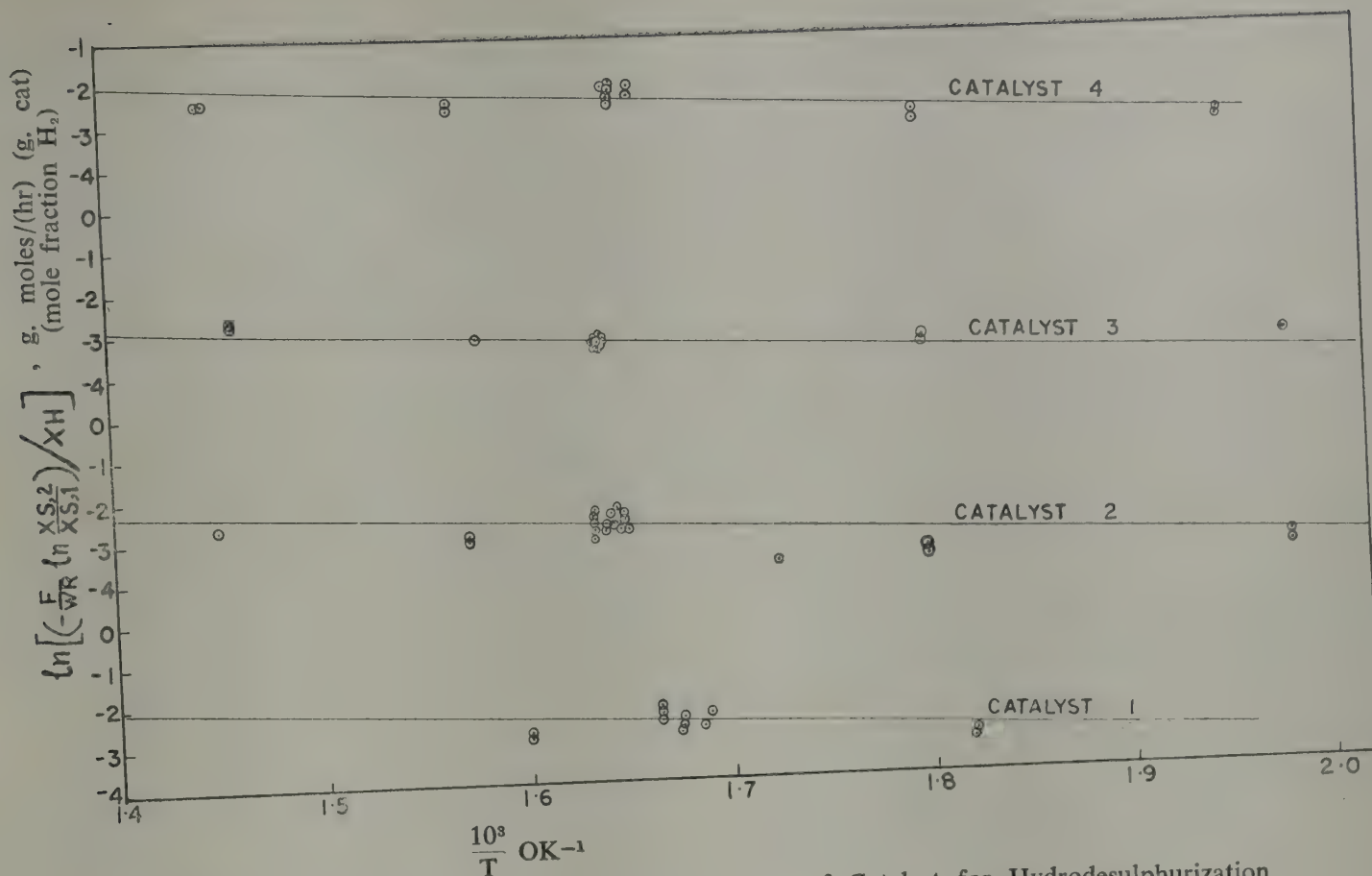


Fig. 1—Optimization of Cobalt Molybdate Type of Catalyst for Hydrodesulphurization.

value of this particular variable is then obtained by dividing by $(n+1)$ the difference of sum total of test values of desired objective for the above two groups

of $\frac{(n+1)}{2}$ tests. Best paths for the variables are then

indicated as $(\text{Base level} + \text{Effect per unit} \times \text{Unit value} \times N)$ where N might be any suitable number. Several best paths are then selected and the optimum condition, i.e. the optimum value of N is obtained by trials on some of the best paths. These trials are necessary since the effect per unit obtained at base level may not hold at levels quite removed from the base level.

Application of the Worksheet for Optimum Composition of Cobalt-Molybdate Type of Catalyst: Since most of the cobalt-molybdate type of catalysts studied uses CoO/MoO_3 molar ratio between 0.65-1.0 with CoO concentration between 2.0-4.4 per cent by wt, the base level of catalyst composition is selected as 2.5 per cent CoO , 5.0 per cent MoO_3 with 0.25 per cent NiO as promoter and rest Al_2O_3 . The variable factors to be studied are CoO , MoO_3 and NiO , the units of which are taken as 1.0, 2.0 and 0.1 per cent respectively. Hence, the high and low levels are as follows:

Factors	High level, %	Low level, %
CoO	3.5	1.5
MoO_3	7.0	3.0
NiO	0.35	0.15

Since our desired objective is to get maximum rate of hydrodesulphurization of petroleum feedstock four samples tests are made with the following catalysts (Table 1) and the test values of rate data noted.

From these sample tests, effect/unit value of the factors (active components) are calculated as:

$$\text{Effect/unit value of CoO} = \frac{(r_1 + r_4) - (r_2 + r_3)}{4}$$

$$\text{Effect/unit value of MoO}_3 = \frac{(r_1 + r_2) - (r_3 + r_4)}{4}$$

$$\text{Effect/unit value of NiO} = \frac{(r_2 + r_4) - (r_1 + r_3)}{4}$$

where r_1 , r_2 , r_3 and r_4 are the test values of rate with catalyst samples 1, 2, 3 and 4 respectively.

Best paths are then indicated as:

Percent by wt of a particular factor (active component) = $\text{Base level} + (\text{effect/Unit value}) \times (\text{unit value}) \times (N)$, where N is any number.

TABLE 1—PERFORMANCE OF TEST CATALYSTS

Test Catalyst No.	Composition, wt. %				E, Energy of Activation, g. cal./g. mol.	K _H , Velocity Coefficient g. mole/(hr) (g. cat.) (molefraction H ₂)	Size-diameter × length, mm × mm	Pore length, $\bar{L} = \frac{V_p}{S_x} \sqrt{2}$, mm	Values of k _H Based on Pore Length = 1.50 mm, g. mole/(hr) (g. cat.) (molefraction H ₂)
	CoO	MoO ₃	NiO	Al ₂ O ₃					
I	3.5	7.0	0.15	Balance	3974	1.82	5 × 12	1.465	1.78
II	1.5	7.0	0.35	„	3974	1.49	5.4 × 10.6	1.520	1.51
III	1.5	3.0	0.15	„	3974	0.91	4.9 × 11.85	1.435	0.87
IV	3.5	3.0	0.35	„	3974	2.22	5.6 × 9.5	1.530	2.27

Experimental

Preparation of Catalyst: Alumina gel obtained by addition of dilute ammonia liquor to a hot solution of aluminium nitrate was digested for 3 hours at 50°C and then left under room conditions for about 60 hours. This is then filtered, washed with 0.5 per cent NH₃, dried and calcined at 260-300°C for 3 hours and ground to fine powders. The alumina powders were then mixed with about 0.3 per cent by wt of magnesium stearate, necessary quantities of ammonium molybdate, cobalt nitrate and nickel nitrate solutions and nitric acid was added, mixed thoroughly, and the pasty mass formed into 5-6 mm. diameter pellets. The pellets were dried slowly and calcined at 260-300°C for 3 hours and then at 500-550°C for 6 hours. The pellets were cut into 10-12 mm. lengths before testing for its performance.

Test Procedure and Results

The catalysts were tested in the same way and in the same apparatus as used in our previous studies¹⁸⁻²⁰. Ethyl mercaptan in heptane solution was used in all the cases for determination of the rate of hydrodesulphurization. Space velocity, mole fraction H₂ at inlet and temperature were varied under total pressure of one atmosphere. The data were correlated in the same way as in our previous studies¹⁷⁻¹⁹ by plotting in

$$\left[\left(-\frac{F}{W_R} \ln \frac{X_{S,2}}{X_{S,1}} \right) / x_H \right]$$

g.moles/(hr) (g. cat.) (molefraction H₂) against $\frac{1}{T} \ln K - 1$

(Figs. 1-4). The results could be expressed in the form of $r = \text{rate, g.moles/(hr) (g. cat.)}$

$$= -\frac{F}{W_R} \ln \frac{X_{S,2}}{X_{S,1}} = k_H e^{-E/RT} x_H.$$

Values of E, g. cal./g-mole and k_H, g.moles/(hr) (g. cat.) (mole fraction H₂) for the different test catalysts have

been shown in Table 1. In Table 2 a worksheet for determining the optimum composition of catalyst, the desired objective being maximum rate of hydrodesulphurization, has been drawn as per Li¹⁷.

TABLE 2—WORK SHEET FOR CATALYST DEVELOPMENT FOR MAXIMUM RATE OF HYDRODESULPHURIZATION AND MAXIMUM VELOCITY COEFFICIENT

	Wt. of variable factors (active components), %			K _H , Velocity Coefficient Data Based on Equivalent Pore Length of 1.50 mm. g. moles (hr) (g. cal.) (molefraction H ₂)
	CoO	MoO ₃	NiO	
<i>Variable Factors</i>				
Base level	2.5	5.0	0.25	
Unit	1.0	2.0	1.10	
High Level	3.5	7.0	0.35	
Low Level	1.5	3.0	0.15	
<i>Sample Tests</i>				
1	3.5	7.0	0.15	1.78
2	1.5	7.0	0.35	1.51
3	1.5	3.0	0.15	0.87
4	3.5	3.0	0.35	2.27
<i>Effect on K_H per unit of variable factors</i>				
	0.4175	0.0375	0.3075	
<i>Best path = Base level + (Effect/unit) × unit value × N.wt. %</i>				
N = 7	5.42	5.52	0.47	
N = 14	8.34	6.04	0.69	
N = 21	11.26	6.56	0.91	
N = 28	14.18	7.08	1.13	
N = 35	17.10	7.60	1.35	
N = 42	20.02	8.12	1.57	

Since the test results show that the energy of activation E , g.cal./g.mole for all the test catalysts are same, the rate of hydrodesulphurization for all the catalyst samples will be directly proportional to velocity coefficient k_H , g mole/(hr) (g.cat.) (mole fraction H_2) under same conditions of temperature, space velocity and mole fraction H_2 . The desired objective, therefore, is to get maximum velocity coefficient. The test catalysts slightly differ in their sizes. To eliminate the effect of size variations pore lengths of the different sizes of catalysts were calculated by the method given by Smith²⁰. The values of effective velocity coefficients for an equivalent pore length of 1.50 mm. are then calculated on the basis of inverse relation of effectiveness to pore length²¹, and these have also been shown in Table 1.

Conclusion

Test results show that the effect per unit of CoO and NiO is much higher than that for MoO₃, so it is expected that for alumina supported and nickel promoted catalyst optimum composition have CoO more than MoO₃. This is interesting, since except in one reference¹⁴ cobalt molybdate type of catalysts have been found to contain more of MoO₃ than of CoO on wt per cent basis.

Six best paths have been indicated in the worksheet. To find the optimum composition, we have made a program for testing best path nos. 1, 2, 4 and 6 and work in this line is in progress. The results of these trials will be published in the next part of this series.

Nomenclature

e	= constant 2.72.
E	= energy of activation g.cal./g.mole.
F	= total feed, g.moles (hydrogen+hydrocarbon)/hr.
k_H	= velocity coefficient, g.moles/(hr) (g.cat.)(mole-fraction H).
\bar{L}	= pore length = $\frac{V_P}{S_X} \sqrt{2}$, mm.

n	= No. of effective variables.
N	= any number.
r	= rate of hydrodesulphurisation g.mole/(hr) (g.cat.).
R	= gas constant, 1.987 g.cal./(g.mol) (o _K).
S_X	= internal surface of a catalyst particle, mm ² .
T	= absolute temperature, o _K .
V_P	= volume of a catalyst particle, mm ³ .
W_R	= wt of catalyst, gms.
X_H	= molefraction of hydrogen infeed.
$X_{S,1}$	= molefraction of sulphur compound at inlet to the catalyst bed.
$X_{S,2}$	= molefraction of sulphur compound at outlet from the catalyst bed.

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Ureolytic Bacteria in Soils

Part III—Volatilization Loss of Ammonia from Urea on Soil Application

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Urea on soil application is hydrolyzed quickly, and a considerable part of ammonia so released tends to volatilize into the atmosphere. The results of investigation on the degree of such loss under different soil conditions are discussed. On soil surface application of urea, volatilization losses of 25.2 to 30.91 per cent at 30°C and 3.4 to 10.0 per cent at 18-25°C have been noted. If urea is applied a few inches below the surface, the extent of such loss is virtually negligible. Though water-logging and acidic soils tend to minimize the loss to some extent, soil moisture contents of 40 and 60 per cent saturation have no such effect.

In the course of investigations^{5,6} on the transformation of urea in soils, gaseous ammonia was always detected in air above the soil surface in the experimental glass vessels. As the control vessels not containing any urea but kept under identical conditions did not reveal any such gases, the ammonia must have come through volatilization from urea as a result of microbial hydrolysis in soil. A glance through literature reveals that similar losses of ammonia from urea have been noted earlier by Mitsui¹ et al, Ernst and Massey², Purvis⁴ and Volk³. Thus, though the problem of volatilization loss of ammoniacal nitrogen from urea has attracted some attention, very little information on the extent of such losses and its economic implication are available at present. A study of the problem was, therefore, undertaken and the results are discussed herein.

Methods and Materials

Soils were collected from the paddy fields of Farm No. 1 of this division and brought to suitable granular size and moisture content. 100 g. of the soil samples were then taken in 250 ml. gas washing bottles. To the soil surface in the bottle (approx. 13 sq. cm), a calculated amount of water was added to bring the moisture level of the soil to the desired range. Urea was applied uniformly over the whole soil surface. The bottle was then connected in series with other vessels containing

2.5 per cent sulphuric acid and water at one side and 100 ml. of 4 per cent boric acid at the other. All connections through rubber tubings were made air-tight and air was then drawn through the system by a water suction pump at the rate of about 1 l./hr. As the air was first bubbled through sulphuric acid and washed in ammonia-free water, any ammoniacal nitrogen, absorbed in boric acid and estimated by titration with a standard acid as a result of bubbling of the outgoing air through it, must have come from the soil. The control without application of urea was similarly treated and the difference in ammoniacal nitrogen absorbed in boric acid was treated as loss of nitrogen from urea through volatilization.

For the deep application of urea, only a smaller amount of soil was taken in the bottle in order to get a soil column of about 1/2" and urea was applied on the surface uniformly. The rest of the soil was then added in order to have a soil column of 2" above the surface of urea application. The moisture content of soil was then adjusted by adding the required amount of water on soil surface. As the experiments were conducted during November to February, the experimental vessels were maintained at 30°C by dipping the bottle partially in a thermostatically controlled water-bath so that whole of the soil column was immersed.

Results and Discussions

The results represent the loss of ammoniacal nitrogen through volatilization from urea applied on soil surface in 15 days (Table 1). It is quite evident from the data presented that like all biochemical reactions, temperature has a marked influence on the process. While the extent of loss of nitrogen from soil surface-applied urea varied from 3.4 to 10.0 per cent at room temperatures ranging from 18-25°C, the same at 30°C increased to 25.20 to 30.91 per cent. When urea is applied about 2" below the soil surface, the volatilization loss, however, has been spectacularly reduced to 0.0 to 0.5 per cent and 0.39 to 0.69 per cent at room temperature and 30°C respectively. The leaching out of ammoniacal nitrogen from these soils at the end of the experiments by 6 per cent NaCl at pH. 1, has shown that urea, even if applied 2" below the surface, is easily hydrolyzed. The marked reduction in volatilization loss from deep application of urea must be attributed to the contact of ammonium ions with soil clay particles and their subsequent adsorption during diffusion upwards.

The effect of soil moisture on volatilization loss was also demonstrated and the results are given in Table 2. It may be seen from the data that the volatilization loss of ammoniacal nitrogen is only 3.41 to 11.4 per cent if the soils are maintained under water-logged conditions with about 5 mm. water above the soil surface, as against 21.61 to 33.12 per cent from soils with 40 and 60 per cent saturation. This considerable reduction of nitrogen loss in water-logged soil may be attributed to the diffusion of ammonia into deeper soil water. This would increase the contact of ammonium ions with soil clay particles and hasten its adsorption.

The volatilization loss is not only dependent on soil temperature and moisture but also on some other soil properties. Soil reactions are likely to influence it. The different soils of Bihar varying in pH were, therefore, tested and the results are shown in Table 3.

Acidic, alkaline and neutral soils from Netarhat, Monghyr and Bhagalpur were collected and compared with Sindri soils, with respect to nitrogen loss from the surface-applied urea. It can be seen (Table 3) that 23.1 per cent loss was recorded from Netarhat soil with pH 5.4, the corresponding loss being 30.8, 34.3 and 30.3 per cent from Monghyr (pH 8.0), Bhagalpur (pH 7.2) and Sindri (pH 7.8) soils respectively. Thus, though the losses are quite considerable from all soils, a slight reduction in volatilization loss from acidic soils of Netarhat is noteworthy.

TABLE 1—PERCENTAGE LOSS OF AMMONIACAL NITROGEN THROUGH VOLATILIZATION IN 15 DAYS AFTER APPLICATION OF UREA FOR SOIL

Nature of Application	Room Temperature 18-25°C			Water-bath Temperature 30°C		
	Experiments			Experiments		
	I	II	III	I	II	III
Soil surface	10.0	5.1	3.4	27.01	25.20	30.91
2" below the soil surface	0.5	0.11	0.0	0.46	0.39	0.69

TABLE 2—EFFECT OF SOIL MOISTURE ON THE VOLATILIZATION LOSS (%) OF AMMONIACAL NITROGEN AFTER UREA APPLICATION (30°C)

Experiments	Moisture Content of Soil		
	40% Saturation	60% Saturation	Water- logged
I	27.46	29.46	11.40
II	24.50	21.61	3.41
III	32.19	33.12	9.48

TABLE 3—VOLATILIZATION LOSS OF AMMONIACAL NITROGEN (%) AFTER APPLICATION OF UREA ON SOIL SURFACE (30°C) IN RELATION TO pH OF THE SOIL

Different Soils	pH	Loss of NH ₃ -N, %
Netarhat soil	5.4	23.1
Bhagalpur soil	7.2	34.3
Monghyr soil	8.0	30.8
Sindri soil	7.8	30.3

The daily rate of nitrogen loss from the surface-applied urea has also been studied (Fig. 1). It can be seen that the nitrogen loss is slow at first but soon reaches its peak in 4-5 days and sharply declines later on. It has also been shown earlier^{5,6} that the rate of hydrolysis of urea in soil is slow during the first 24 hours after application but soon shoots up to its peak during 48-72 hours. It is not difficult to understand that the volatilization of ammonia follows very closely the rate of urea hydrolysis by soil microorganisms and these two events are closely related. As has been reported earlier^{5,6}, urea hydrolysis is more or less complete in most of the Bihar soils in 5-7 days. The greater bulk of volatilization loss will, therefore, occur within that period or soon thereafter. In fact it has been noted that more than 92, 86 and 75 per cent of the total losses

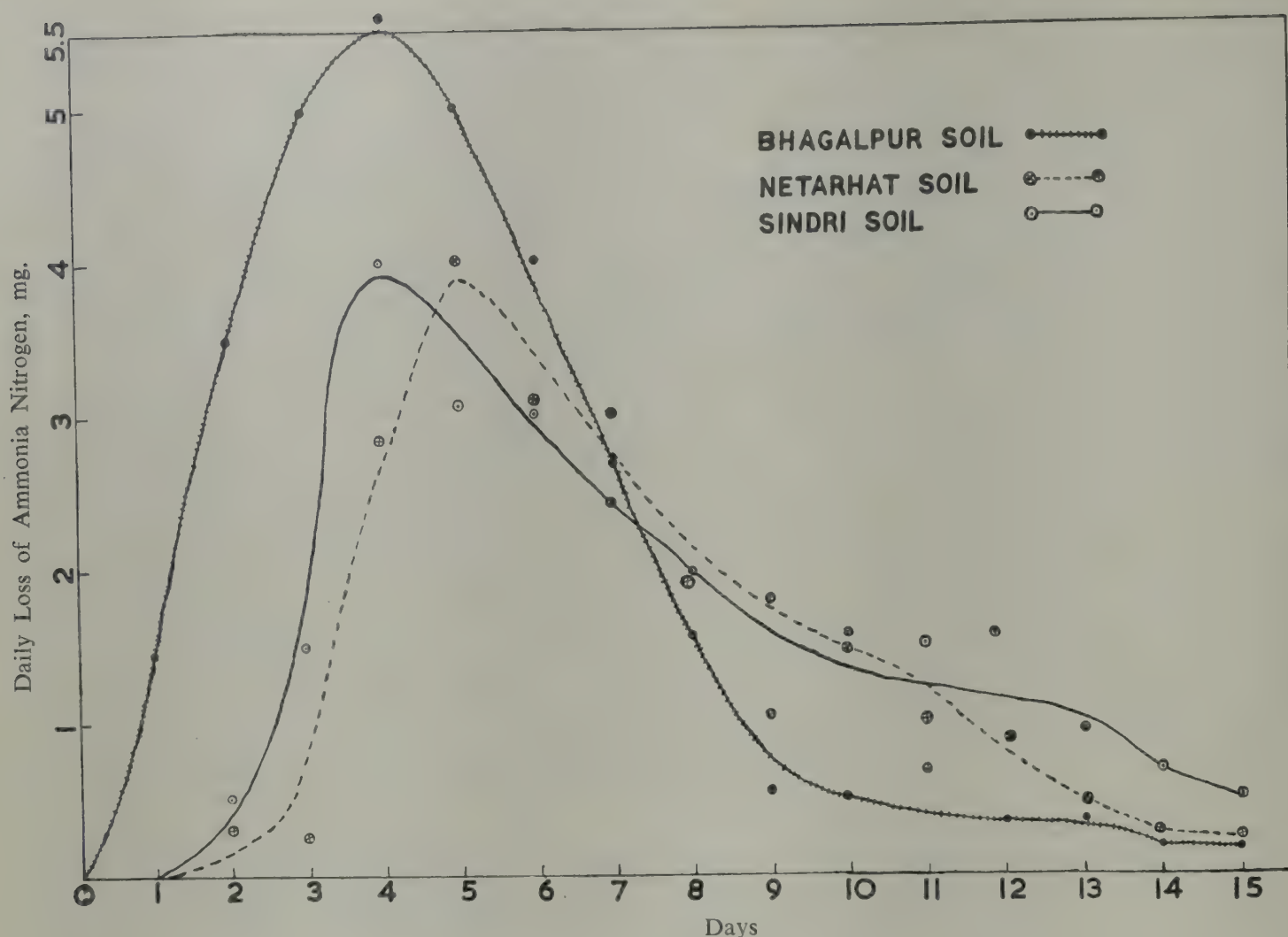


Fig. 1

have occurred from Bhagalpur, Netarhat and Sindri soils respectively in 10 days.

Conclusion

The results on the volatilization loss of Ammonia from urea applied on soil surface have been presented. This has been shown to vary at 30°C from 21.6 to 34.3 per cent of the total urea nitrogen applied in 15 days. Volk³ had recorded 20.6 and 59 per cent loss of ammonia in 6-8 days from urea applied to grass sods and bare soils respectively. Though the results indicate that the extent of loss is considerably reduced at lower temperature (18-25°C), the problem is likely to assume serious magnitude under the greater part of Indian field conditions where temperatures higher than 30°C generally prevail. The water-logging of soil has also been shown to reduce volatilization of ammonia but soil moisture of 60 per cent saturation or loss has no such effect.

The rate of volatilization loss is slow at first but soon attains its peak and then steadily declines to the minimum. As has already been pointed out, this follows closely the trend of urea hydrolysis by microorganisms. Thus, though the volatilization of ammonia from urea

may be detected for over a month or so, 75-92 per cent of the loss can be accounted for during the first 10 days.

This seems to be too short a period for any crop to cope up with the loss. The problem is still aggravated by the fact that the ammonia released from urea but still retained in soil is easily nitrified and liable to quick loss through leaching and denitrification by soil microorganisms.

Acknowledgement

Our thanks are due to Dr. K. R. Chakravorty, General Manager, and Sri B. K. Dutta, Deputy Superintendent, Planning and Development Division, for their keen interest during the progress of the work.

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Role of Zn^{2+} in Improving Corrosion Inhibition of Mild Steel by Chromate-Polyphosphate Combination in Cooling Water

By

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Corrosion inhibition of mild steel in cooling waters by chromate (40 ppm. as CrO_4) and polyphosphate (20 ppm. as PO_4) has been found to be considerably improved by the presence of Zn^{2+} added in the form of zinc sulphate. The addition of zinc in the form of sodium zinc polyphosphate has also been found effective.

Chromate-polyphosphate combination has been found¹⁻⁹ to be an efficient inhibitor for corrosion of mild steel in cooling waters. Though it considerably reduces the rate of corrosion, etching or pitting is observed under certain conditions on the surface of mild steel. Bregman¹⁰ and Newman¹¹ showed that polyphosphate (25 mg./l.) in combination with certain multivalent ions has a good inhibitor action in circulating water systems. A method¹² presented for treating circulating water based on zinc alkali metal polyphosphate in combination with chelating agent provides better scale and corrosion control. Zinc chromate-organic¹³ combination as inhibitor has also been used for controlling corrosion in an open circulating cooling water. Kleber¹⁴ described the use of bimetallic glassy phosphates for corrosion control in municipal water.

In the present investigation, various mixtures of zinc, polyphosphate and chromate have been studied for improving the corrosion inhibition by chromate-polyphosphate combination in cooling waters. Sodium zinc polyphosphate glasses of different composition were prepared, and they were used in combination with chromate. The combination, zinc sulphate+chromate+polyphosphate, was also studied.

Experimental

Sodium polyphosphate and sodium zinc polyphosphate glasses were prepared by heating sodium di-

hydrogen orthophosphate and a mixture of sodium dihydrogen orthophosphate, diammonium hydrogen orthophosphate and zinc oxide in a platinum dish to 800°C for 1 hour and chilling the molten mass, thus obtained, by pouring on ice-cooled stainless steel plates. The method is the same as used by previous workers¹⁵⁻¹⁸. Samples of sodium zinc polyphosphate glass with varying zinc contents were prepared by changing the compositions (Table 1) of the starting mixtures. The weight average molecular weights (Table 1) of the samples were determined by viscosity method^{15,17,18}.

All the chemicals used were of analytical reagent grade. To study the effect of relatively high concentrations of ammonium nitrate and chloride, experiments were carried out with water samples prepared in the laboratory containing 500 ppm. of ammonium nitrate and 100 ppm. of sodium chloride (Table 2).

Experiments were also carried out with prepared water samples having the following analysis: Ammoniacal N 80 ppm.; Nitrate N 52 ppm.; Cl 20 ppm.; SO_3 70 ppm.; and Ca 40 ppm.

These corresponded to the analysis of miscellaneous service cooling tower water from the gas reformation plant at Sindri.

Experiments were carried out in a thermostat maintained at a temperature of $40 \pm 0.1^\circ\text{C}$ and the pH of the solution was measured by a Cambridge pH meter.

TABLE 1—CONDITIONS OF PREPARATION AND ANALYSES OF SODIUM POLYPHOSPHATE AND SODIUM ZINC POLYPHOSPHATE
GLASS SAMPLES OF DIFFERENT COMPOSITIONS

Sample	Starting Materials	Time of Heating, hr	Temperature, °C	Weight Average Molecular Weights, Mw	ZnO, %	P ₂ O ₅ , %
Sodium Hexa-meta-phosphate Technical B.D.H.	—	—	—	—	—	63
Sodium Polyphosphate	NaH ₂ PO ₄ , 2H ₂ O	1	700±20°	12,360	—	69.8
Sodium Zinc Polyphosphate (B)	NaH ₂ PO ₄ , 2H ₂ O (4M)+(NH ₄) ₂ HPO ₄ (2M)+ZnO (1M) (4:2:1) glass	1	800±20°	3,154	13.00	65.0
Sodium Zinc Polyphosphate (C)	NaH ₂ PO ₄ , 2H ₂ O (4M)+(NH ₄) ₂ HPO ₄ (1M)+ZnO (0.5M) (4:1:0.5) glass	1	„	3,252	9.68	66.0
Sodium Zinc Polyphosphate (D)	NaH ₂ PO ₄ , 2H ₂ O (4M)+(NH ₄) ₂ HPO ₄ (0.5M)+ZnO (0.25M) (4:0.5:0.25) glass	1	„	3,353	5.85	67.2
Sodium Zinc Polyphosphate (E)	NaH ₂ PO ₄ , 2H ₂ O (4M)+(NH ₄) ₂ HPO ₄ (0.2M)+ZnO (0.1M) (4:0.2:0.1) glass	1	„	3,693	2.66	68.7
Sodium Zinc Polyphosphate (F)	NaH ₂ PO ₄ , 2H ₂ O (4M)+(NH ₄) ₂ HPO ₄ (0.1M)+ZnO (0.05M) (4:0.1:0.05) glass	1	„	3,864	1.30	69.4

The procedure for the preparation of mild steel coupons and of corrosion testing was the same as described earlier¹⁻³.

A series of corrosion experiments were performed with high amounts of sodium chloride (100 ppm.) and ammonium nitrate (500 ppm.). Various forms of polyphosphates, singly or in combination with chromate, were tried as corrosion inhibitors (Table 2). Along with chromate, sodium-zinc polyphosphate samples with varying amounts of zinc were added; zinc sulphate in different amounts were also added to chromate-polyphosphate combination and the effects of the combinations were studied. (Tables 3 and 4).

The effect of addition of Zn²⁺ in combination with chromate and polyphosphate was also studied on the corrosion of mild steel in waters containing high amounts of dissolved sulphate (Table 5).

Results and Discussion

In Table 2 are given the results of corrosion experiments in which a relatively high concentration of sodium chloride (100 ppm.) was maintained in water

containing 500 ppm. of ammonium nitrate. The corrosion rate of mild steel in water without any inhibitor was as high as 337.8 mg./sq.dm/day. When chromate or chromate+polyphosphate is used as the inhibitor, corrosion is considerably reduced but there is pitting or etching on the surface of mild steel test coupons. The etching and pitting are, however, completely eliminated when chromate and sodium zinc polyphosphate sample B (containing 13% ZnO) is used (Table 3).

From Table 3, it will be observed that at the same level of chromate and polyphosphate application, corrosion rate was less and surface of test coupon was much better when sodium zinc polyphosphate samples B (13.00% ZnO), C (9.68% ZnO) and D (5.85% ZnO) were used than when a commercial sample of polyphosphate was used. Sodium zinc polyphosphate samples E and F, containing lower amounts of ZnO viz. 2.66% and 1.30 per cent respectively, were not so effective as samples B, C and D. Good inhibition of corrosion of mild steel test coupons and clean surfaces are also obtained when certain amounts of zinc sulphate are present in the water along with chromate (40 ppm. as CrO₄) and polyphosphate (40 ppm. as PO₄) (Table 4).

TABLE 2—CORROSION OF MILD STEEL IN WATERS OF VARIOUS COMPOSITION, WITH AND WITHOUT INHIBITORS IN PRESENCE OF 100 ppm of NaCl+500 ppm of NH_4NO_3 (Temp. 40°C ; pH—7.0)

Nos.	Composition of Water and Inhibitor Used	Corrosion Rate mg/sq. dm/ day	Remarks
1.	Sodium Chloride+ NH_4NO_3 without inhibitor	337.8	Highly Corroded
2.	$\text{NaCl}+\text{NH}_4\text{NO}_3$ +Chromate (40 ppm. as CrO_4)+Polyphosphate (20 ppm.) as PO_4 from technical hexametaphosphate	29.2	Slightly corroded with pitting
3.	$\text{NaCl}+\text{NH}_4\text{NO}_3$ +Chromate (40 ppm. as CrO_4)+Polyphosphate (20 ppm. as PO_4) from Sodium zinc polyphosphate glass sample (B)	27.1	Slightly corroded with smooth surface
4.	$\text{NaCl}+\text{NH}_4\text{NO}_3$ +Chromate (40 ppm. as CrO_4)+ CaSO_4 (123 ppm.) without any polyphosphate	39.7	Slight corrosion with pittings
5.	$\text{NaCl}+\text{NH}_4\text{NO}_3$ + CaSO_4 (123 ppm.)+Polyphosphate (20 ppm. as PO_4) from technical hexametaphosphate. No chromate added	21.3	Slightly corroded but no pitting
6.	$\text{NaCl}+\text{NH}_4\text{NO}_3$ + CaSO_4 (123 ppm.)+Polyphosphate (20 ppm. as PO_4) from Sodium Zinc Polyphosphate sample (B)	23.0	Slightly corroded with smooth surface

TABLE 4—CORROSION AND INHIBITION OF MILD STEEL IN WATER SAMPLES CONTAINING COMBINATIONS OF CHROMATE, SODIUM POLYPHOSPHATE AND VARYING AMOUNT OF ZINC SULPHATE AS INHIBITOR (pH—7.0; Temp. 40°C)

Nos.	Inhibitor Used	Corrosion Rate, mg./sq. dm/ day	Remarks
1.	Chromate (40 ppm. as CrO_4)+Sodium Polyphosphate (20 ppm. as PO_4)	14.0	Etching
2.	Chromate (40 ppm. as CrO_4)+Sodium Polyphosphate (20 ppm. as PO_4)+ ZnSO_4 (10 ppm.)	6.7	Slight etching
3.	Chromate (40 ppm. as CrO_4)+Sodium Polyphosphate (20 ppm. as PO_4)+ ZnSO_4 (5 ppm.)	5.5	Clean surface
4.	Chromate (40 ppm. as CrO_4)+Sodium Polyphosphate (20 ppm. as PO_4)+ ZnSO_4 (2.5 ppm.)	4.3	„

TABLE 3—CORROSION AND INHIBITION OF MILD STEEL IN PREPARED WATER SAMPLES, CONTAINING COMBINATION OF CHROMATE AND SODIUM ZINC POLYPHOSPHATE GLASS OF VARYING COMPOSITION

(pH—7.0; Temp. 40°C)

Nos.	Inhibitor Used	Corrosion Rate mg/sq. dm/ day	Remarks
1.	No inhibitor	139.0	Highly corroded
2.	Chromate (40 ppm as CrO_4)+Sodium Hexametaphosphate (B.D.H.) (20 ppm. as PO_4)	14.1	Etching
3.	Chromate (40 ppm. as CrO_4)+Synthetic Sodium Polyphosphate, sample I (20 ppm. as PO_4)	7.0	Slight etching
4.	Chromate (40 ppm. as CrO_4)+Sodium Zinc Polyphosphate sample (B) (20 ppm. as PO_4)	7.8	Clean surface
5.	Chromate (40 ppm. as CrO_4)+Sodium Zinc Polyphosphate sample (C) (20 ppm. as PO_4)	7.7	-do-
6.	Chromate (40 ppm. as CrO_4)+Sodium Zinc Polyphosphate sample (D) (20 ppm. as PO_4)	7.6	Very slight etching
7.	Chromate (40 ppm. as CrO_4)+Sodium Zinc Polyphosphate sample (E) (20 ppm. as PO_4)	11.0	Slight pitting
8.	Chromate (40 ppm. as CrO_4)+Sodium Zinc Polyphosphate, sample (F) (20 ppm. as PO_4)	15.0	-do-

From Table 5, it is clear that zinc definitely improves the corrosion inhibition of mild steel by chromate-polyphosphate combination, whether it is added in the form of zinc sulphate or as sodium zinc polyphosphate when measured by loss in weight.

Acknowledgement

The authors wish to thank Dr. K. R. Chakravorty, General Manager, for his interest in this work.

TABLE 5—EFFECT OF VARYING CONCENTRATIONS OF Zn^{2+} ON THE CORROSION RATE OF MILD STEEL IN WATER SAMPLE CONTAINING COMBINATION OF CHROMATE AND POLYPHOSPHATE WITH HIGHER SULPHATE CONTENTS

(pH—7.0; Temp. °C)

Inhibitor Used	SO ₄ , ppm.	Corrosion Rate, mg/sq. dm/ day	SO ₄ , ppm.	Corrosion Rate, mg/sq. dm/ day	SO ₄ , ppm.	Corrosion Rate, mg/sq. dm/ day	SO ₄ , ppm.	Corrosion Rate, mg/sq. dm/ day
1. Chromate (40 ppm. as CrO ₄)+Polyphosphate (20 ppm. as PO ₄) without zinc	96 (Initial)	8.4	360	8.7	480	14.4	600	31.9
2. Chromate (40 ppm. as CrO ₄)+Polyphosphate (20 ppm. as PO ₄)+Zn SO ₄ (2.5 ppm.)	—	—	„	7.0	„	12.0	„	27.2
3. Chromate (40 ppm. as CrO ₄)+Polyphosphate (20 ppm. as PO ₄)+Zn SO ₄ (5 ppm.)	—	—	„	8.0	„	12.0	„	21.5
4. Chromate (40 ppm. as CrO ₄)+Polyphosphate (20 ppm. as PO ₄)+Zn SO ₄ (10 ppm.)	—	—	„	10.0	„	14.4	„	10.9

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Protection Through Rod Gaps

By

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This paper describes how horn gaps are used in this country on bushings of power transformers, and circuit breakers, post insulators and insulator strings of transmission lines as a back-up protection against transient over-voltages. It pinpoints that their use as such is inherently hazardous if they are not judiciously designed and employed. They will give rise to frequent flash-overs and thereby outages even with minor surges. With low operating voltages it further suggests that duplex horn gaps in place of plain air gaps may be used or plain air gaps should be completely removed to avoid birdage hazard. It gives principles on the basis of which the insulation coordination is achieved between the horn gaps and the equipments they protect. Lastly, it recommends only the restricted use of these horn gaps. It discourages the use of such gaps on vitally connected systems and suggests that even on systems where service and maintenance are important factors these gaps duly compromised may only be used.

Introduction

Besides lightning arresters, gaps are used in this country for sub-station back-up protection. Rod gaps are also installed on the insulator strings of transmission lines as a safeguard against transient over-voltages. These are erected on bushings of power transformers, post insulators, etc. in the urban and rural supply systems. These gaps are found to be inherently hazardous if not designed and employed judiciously. For instance, a number of incidents have occurred where the transformer bushings with horn or rod gaps were shattered to pieces due to birdage. As will be shown later, such gaps would be very small if they are set to coordinate with the front-of-wave strength of the equipment to be protected. Such gaps installed on low-power 11 KV transformers were bridged even by small birds, like sparrows, and the outages became so frequent that they had to be removed or replaced with duplex horn gaps.

The rod gaps also caused prolonged breakdowns when bushings of power transformers were smashed. Line outages were also reported through birdage on suspension and tension strings fitted with horn gaps, which if correlated with the front-of-wave strengths of the apparatus will have a low spark-over voltage on a slow impulse or for 50 cycles. They will, thus, give rise to frequent flash-overs and thereby outages even with minor surges.

Once the rod gap sparks over, there would be a power follow which could only be sealed off or arrested with the putting out of the controlling circuit breaker. It may, thus, be observed that outages resulting thereby would be highly detrimental to industry having continuous processes or to vital loads engaged on emergency production. The rod gaps should not, therefore, be allowed to spark over, which could only be achieved either through a compromise between the degree of protection required and freedom from unnecessary gap flash-overs or by eliminating such gaps altogether and using lightning arresters instead for insulation co-ordination. Such gaps could be used where reliability of service is not so important. There is, however, already an indication that lightning arresters are quickly replacing rod gaps where service and maintenance are important factors.

Protective Devices

There are three types of protective devices, viz. the rod gap, protective tube and the lightning arrester.

Rod gap is simple to construct and easy to use. It is comparatively cheap too. It has two main disadvantages. It does not valve off power voltage and follow current after it has once flashed-over on the surge voltage. It has the characteristic of having more break-down voltage at short time lags than the other insulation which needs a short gap to discharge surges having

steep wave fronts. It would thus have low flash-over-voltages at long time lags which would result in outages even with minor over-voltages. (Fig. 1).

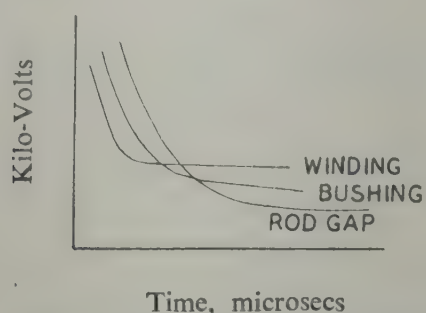


Fig. 1—Voltage—Time Curves.

The rod gaps are only used as a back-up protection where outages with short gaps can be tolerated. Plain air gaps are sometimes used to protect distribution transformers. However, such a device will not restore power voltage after a discharge without de-energizing the circuit. The gap spacings with low operating voltages would be obviously small. These gaps are liable to be bridged even by small birds, thus resulting in outages. For this reason and also for the fact that such gaps do not provide protection against surges of steep wave fronts their use now-a-days is greatly restricted.

Arcing rings or arcing horns were once quite popular. The reasoning given was that the 50 cycles arc could be kept clear of the porcelain and also the impulse flash-over characteristics of the insulator strings were improved. The use of high speed gear for clearing faults and improved porcelain manufacture have practically eliminated the first reason. It has also been established that any device which helps protection of cascading of the arc over the insulator reduces the impulse strength of the insulator.

Uses of Rod Gaps

The impulse characteristics of rod gaps are shown in Fig. 2. These are based on $1.5 \times 40 \mu$ sec. wave. The charts are drawn for different spacings ranging from 5 to 30 in. The curves indicate bent time lags. Table 1 gives standards* of impulse insulation withstand tests for power transformers. Table 2 describes the switching surges which could be expected at various operating voltages. Fig. 3 reproduces 50 cycles dry and wet flash-over voltages for different gap spacings. For judicious approach to the selection of rod gaps reference is required to be made to all these charts and tables.

* British standards and practices.

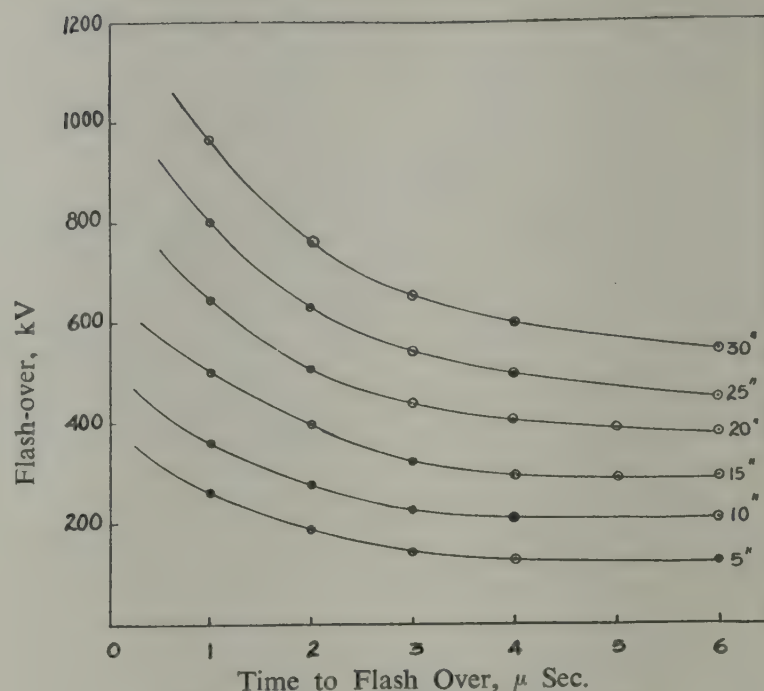


Fig. 2—Characteristics of Rod Gaps.

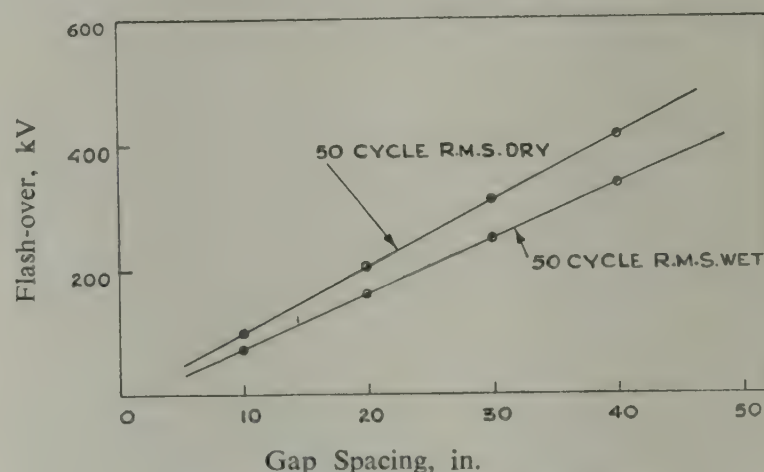


Fig. 3—Protection through Rod Gaps.

TABLE 1—IMPULSE INSULATION WITHSTAND TEST FOR POWER TRANSFORMERS

Insulation Class K.V.	Front of Wave		
	Voltage K. V. Crest	Time to Flash-over, μ Sec.	Full Wave K. V. Crest
33	330	0.5	190
66	550	0.6	335
132	930	1	620
220	1350	1.35	1000

To illustrate the use of these charts and tables some examples are considered. Take the case of a transformer with insulation class 33 KV R.M.S. The front-of-wave voltage for this transformer is 330 KV crest with 0.5 μ sec. time to flash over. Since this impulse flash-over voltage of the rod gap is to correlate with 330 KV

TABLE 2

Voltage Class K. V.	Max. Expected Switching Surge Voltage, K. V.
33	107
66	215
132	430
220	717
380	1239

with 0.5 μ sec. time lag, its spacing could not be more than 5". As a matter of fact, according to Fig. 2, 4 inch gap spacing with 300 KV as flash-over voltage would only allow some margin of safety. Now referring to Fig. 3 the dry and wet 50 cycles flash-over voltages for 5" gap spacing are only 47 KV and 37 KV respectively. The maximum switching surge corresponding to 33 KV operating voltage according to Table 2 will be 107 KV. It may thus be seen that the gap spacing of 4 inches which really gives protection to the transformer does not satisfy other working conditions. Such a gap will spark-over even with minor over-voltages. It may thus be necessary to evolve a compromise if the rod gap is to be used as a protective device. The author selected a 6 inches gap. Although this air gap will have a somewhat higher flash-over-voltage on steep wave than the front-of-wave voltage of the transformer for the same time lag, it will not cause unnecessary operations of the gap with minor over-voltages.

Similarly, taking the case of 66 KV insulation class transformer we need a gap of roughly 13 inches which gives flash-over voltage of 500 KV against 550 KV crest of the transformer, thus leaving a safety margin of 50 KV for the same time lag. Referring to Fig. 3, for 13 inches gap dry and wet 50 cycles flash-over voltages are 130 KV and 99 KV against expected minimum switching surge voltage of 215 KV. It may, thus, be observed that even with minor switching surges in the system such a rod gap will flash-over. It will be useful to effect a compromise here also to avoid outages through surges and birdage.

For insulation class above 110 KV, chances of the birds bridging the gaps are remote. These gaps need only to be studied from the point of view of switching surges. For 132 KV insulation class transformer the gap required is 27 inches which corresponds to a flash-over voltage of 860 KV against 930 KV crest of the transformer for 1 μ sec. time lag. This leaves a safety margin of 70 KV. Now referring to Fig. 3, 50 cycles

dry and wet flash-over voltages corresponding to this gap are 280 and 220 KV respectively. The maximum switching surge voltage which could be expected on such a system is 430 KV. The probability of such a gap sparking over on minor switching surges is, therefore, not ruled out.

Switching Surges

Perhaps, it may be useful to describe here a little about switching surges. When a circuit comprising long transmission lines is de-energized through a circuit breaker, the line remains charged, and the voltage which appears across the circuit breaker is twice the normal system voltage at half cycle of the system frequency. If the circuit breaker is closed at that moment the voltage across the line will tend to rise to three times the normal voltage due to circuit inductance. If there is no damping due to losses the voltage may even rise to five times the normal voltage and so on. The same phenomenon repeats where the systems are un-earthed or earthed through high reactances. When a line-to-ground fault occurs the voltage of the unfaulted phase rises to line-to-line voltage. The switching surges which would appear on nongrounded systems would thus be severer in that the voltage across the line would then increase in the proportion $\sqrt{3}$ (1, 3, 5, ...). In practice, however, it may not be so as due to damping the voltage rise due to switching surges would be greatly restricted and only in certain instances we may come across the voltages rising beyond 3 times normal system voltage.

This only gives a theoretical aspect of the problem. Complicated circuits would need a comprehensive study to fix their protective levels.

Conclusion

The following are the conclusions:

- (1) The rod gap as protective device may be used on systems where continuity of supply is not so important.
- (2) The rod gap duly compromised may only be used as a back-up protection on systems where service and maintenance are important factors.
- (3) Particular care should be taken in the use of rod gap on systems operating at 66 KV and below to minimise chances of outages through birdage.
- (4) For vitally connected systems the use of rod gap should be avoided; suitable type of lightning arrestors should be employed instead.

Estimation of Free Acid in Superphosphates by High Frequency Titrimetry

By

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Based upon the high frequency titration technique, a method has been developed for the estimation of free acid in the single and triple superphosphates. In this method the free acid in superphosphate is extracted by a mixture of acetone and ether (1 : 1 by volume), and the extract is titrated against a standard alkali by the high frequency technique.

In the manufacture of the single and triple superphosphates, determination of free phosphoric acid is of considerable importance for the quality control of the products. The methods, so far employed¹, involve the extraction of the free acid by some organic solvent and titration of the extract against a standard alkali using a suitable indicator. However, it is difficult to get accurate estimations of free phosphoric acid by these methods because the indicators used in the titration of the extract give uncertain end-points in the organic media. In order to overcome this difficulty, Yamaze² developed a modified method for determination of free phosphoric acid in superphosphate. In this method, the acid is extracted from the superphosphate in a mixture of acetone and ether in the ratio 1 : 1 by volume and then the organic phase is removed from the extract by evaporation. Water is then added to the residue and the aqueous solution is titrated against a standard alkali using a suitable indicator.

In the present study a method has been evolved for the determination of free acid in superphosphate by the high frequency titrimetry. In this method, there is no interference on the determination of end-point due to the presence of organic media. Actually a sharper end-point is obtained in an organic medium than in an aqueous one and also no indicator is necessary.

Procedure

A sample of superphosphate (2-3 g.) is taken in a conical flask (300 ml.) fitted with a standard joint

ground glass stopper. 100 ml. of a mixture of acetone and ether (1 : 1 by volume) is added to the superphosphate. A mixture of acetone and dioxan (1 : 1 by volume) or dioxan alone may also be used as the organic extraction medium. The mass is stirred for 10-12 minutes by means of a magnetic stirrer after tightly closing the mouth of the flask. The stirred mass is then quickly filtered through a dry Whatman filter paper (No. 1), the residue washed with the same organic solvent as used in extraction and the filtrates and washings are made up to 250 ml. in a volumetric flask. From this stock solution measured volumes are taken for the determination of free acid both by the high frequency method and also by the method of Yamaze².

In the high frequency method, 10 or 20 ml. of the stock solution is taken in the titration cell of a high frequency (8 M/cs) titrimeter. The details of the instrument used have been described in previous publications³⁻⁶. The solution is then diluted to 300 ml. with the organic solvent so that both the metallic bands are covered by it. The solution is stirred by a magnetic stirrer except when the readings are taken. A standard alkali solution (0.1 N sodium hydroxide) is added from a microburette in 0.2-0.5 ml. portion. After each addition of the alkali, there is a change in the meter reading of the high frequency titrimeter, which is noted. The meter readings are plotted against the volume of the titrant and a graph is drawn (Fig. 1). The first break in the curve is quite sharp and corresponds to the first neutralization of free phosphoric acid and complete

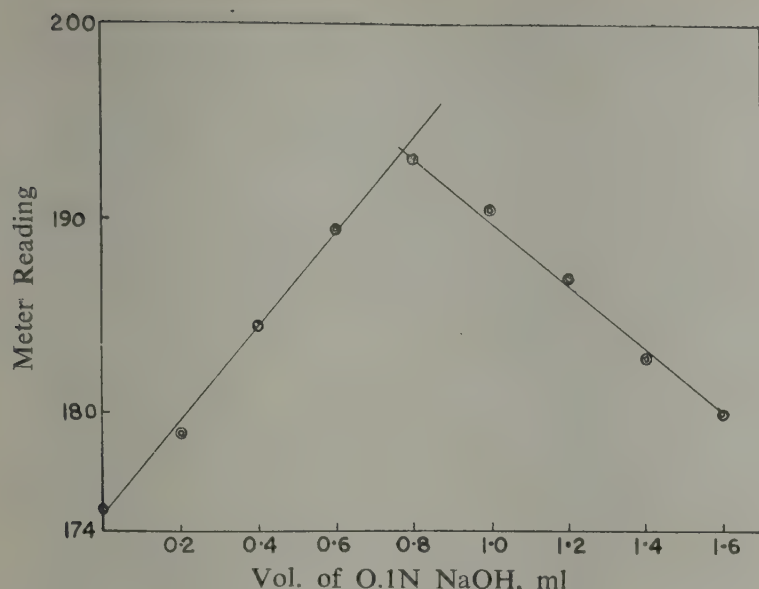


Fig. 1—High Frequency Titration of Free Phosphoric Acid in Superphosphate.

TABLE 1—ESTIMATION OF FREE PHOSPHORIC ACID IN NORMAL AND TRIPLE SUPERPHOSPHATE

Sample No.	Description	Free Phosphoric Acid, %	
		By Indicator Method ^a	By High Frequency Method
1	Fresh normal superphosphate	4.84	4.95
2	-do-	4.35	4.50
3	-do-	6.54	6.40
4	-do-	5.31	5.45
5	Aged normal superphosphate	2.40	2.50
6	-do-	2.15	2.25
7	-do-	2.88	2.70
8	-do-	1.95	2.08
9	Fresh triple superphosphate	12.70	12.85
10	-do-	9.95	9.80

neutralization of the sulphuric acid, if any.

In order to compare the results obtained in the high frequency titration method with that developed by Yamaze, 50 ml. of the same stock solution, as was used in the former method, was taken in a 400 ml. beaker and the solvent was evaporated away slowly on a water-bath. About 100 ml. of hot water was then added; the solution was cooled and titrated against a standard sodium hydroxide (0.1 N) using dimethyl yellow as indicator. The first end-point corresponded to the first neutralization point of phosphoric acid; tests showed that there was no free sulphuric acid in the sample. As will be seen (Table 1), there is a close agreement between the quantities of the free phosphoric acid estimated by the high frequency titration technique and those obtained by the method developed by Yamaze².

Because of its simplicity and accuracy, the high frequency titration method is, thus, suited for the determination free phosphoric acid in the single and triple superphosphates.

Acknowledgement

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Utilization of Coke Breeze for Power Generation

By

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Coke breeze of size 3-7 mm. (B.S.S.) was mixed with coal to the extent of 6 per cent and utilized in a boiler for steam generation. It has been observed from the analysis of grate and fly ashes that the combustion efficiency remained practically unchanged. Erosion and other troubles due to the use of coke breeze, even in such a limited quantity cannot be forecast as the test run continued for a very short period.

Introduction

Coke breeze of below $\frac{1}{2}$ inch size, in greater or small amount, is a necessary accompaniment to all carbonizing practices. The proportion of breeze produced with the coke may reasonably be taken at about 15 per cent of the total. The factors controlling the quantity are many such as coal characteristics, the methods of carbonization, quenching, screening, handling and transport. The production is higher in steel and other industries which utilizes the coke within a specified size limit. The annual production of fine breeze from one million ton steel plant is about 140,000 tons¹. Thus, the question of disposal of coke breeze offers a difficult and costly problem to all industries utilizing coke as majority of them do not have special equipment for its proper utilization.

The common uses of coke fine are its utilization in lean gas production and for sintering of ore², blending with coal charge in coke oven in limited quantities³⁻⁵, briquetting^{6,7} for using as domestic fuel and steam-raising^{8,9}.

The disadvantages in the use of coke breeze are many and are related mainly to the smallness of size, higher ash and moisture contents and high abrasive quality. When there is a high proportion of moisture in the fines, an additional disadvantage arises in screening out the dust. In spite of all these disadvantages, the problem of disposal of coke breeze has an easy solution in its use in steam-raising in specially designed boilers.

The choice of breeze as a fuel is solely on consideration of price per ton which is nearly about one-fifth of that

for coke. In order to obtain the maximum efficiency of utilization, combined with minimum disadvantages, it generally becomes necessary to use special types of plants and to adopt special operating techniques.

The total production of coke breeze in the Sindri Fertilizers Factory is about 90-100 tons/day, and in course of several years a large stock of coke breeze had accumulated. Under normal condition, the power plant authorities of Sindri Unit specify the coke size in the range 7 to 12 mm. (B.S.S.) for use along with coal in their boilers. From the analysis of the accumulated stock of breeze and also the fact that the above 7 mm. size could be profitably used in the lean gas plant, it was considered that Sindri Power Plant should give a trial run using coke-breeze of size 3-7 mm. in its No. 7 boiler to make a preliminary assessment of the utilization of this finer size.

Boiler Operation at Sindri

The power plant has water tube boilers having chain grate mechanism for the combustion of coal. At present the coal used in the boilers has the following characteristics.

Size Analysis (B.S.S.): 25 to 6 mm., 50 per cent; 6 to 3 mm., 18 per cent; below 3 mm., 32 per cent.

Percentage of Ash and Other Characteristics: 24-25 per cent; Ash fusion temperature $>1400^{\circ}\text{C}$.

The overhead bunker feeds coal (size $\frac{1}{8}$ " to $1\frac{1}{4}$ ") to two boilers on two sides. There are four such bunkers, three of which supply coal to the six boilers, while the other supplies to the 7th boiler, which is an isolated

unit distinct from the others in many respects.

Coal from one limb of the bunker is divided into two spreader and falls into a box where the coal is continuously pushed forward by a pusher plate. From the pusher plate coal falls on the concave vanes of a rotor and ultimately thrown to the other end of the grate. Fine coal burns in suspension and by the time the fuel enters the main combustion zone, it gets preheated and ignited.

Recycling of the grit-ash is done in three stages viz. (1) at the boiler outlet, (2) at the economizer outlet and (3) at the air preheater. At the boiler and economizer outlets, separation of the heavier particles is done by baffle arrangements and change of direction of the main stream of gas. At the exit end of air heater there is a Pratt Daniel cyclone dust collector. At all the stages of separation the grit ash falls to a common channel through which the secondary air comes to the grate. From cyclone dust collector, the gas goes to the chimney through the I.D. fans.

Experimental

During the trial run the coal and coke breeze mixture was fed in the boiler No. 7 from 14-6-65. The breeze was about 6 per cent of the total feed. The collection and analysis of samples of coal, coal and coke-breeze mixture, grate-ash and fly-ash were done regularly throughout the trial period in order to find out any difference in the performance when coke-breeze was used with coal. Some data of the boiler performance was also collected for the sake of comparison before the trial was conducted.

Results

Although it was thought that the Power Plant would be supplied with screened coke breeze of size range 3 to 7 mm., in actual operation the fuel for the trial run contained about 50 per cent fines below 3 mm.

Table 1 shows the results of coal screening over a 3 mm. sieve to have an idea of the proportion of coal fines charged in the boiler. The amount of coal fines below 3 mm. is well above 25 per cent (as specified by the boiler suppliers) and often goes as high as 43 per cent.

Table 2 shows analysis of grate and fly ashes before test of No. 7 boiler. It is seen that the average combustible matter carried over with grate ash is 24 per cent and that with fly ash is 55 per cent. In order to compare this value with the average value obtained with other boilers, the grate and fly ashes of all other 6 boilers were

TABLE 1—SCREEN ANALYSIS OF CRUSHED COAL SAMPLES FROM POWER PLANT BUNKER BEFORE TEST RUN.

Dates of Collection	21.5.65	22.5.65	24.5.65	25.5.65	26.5.65	27.5.65	28.5.65
—1/8", %	27.5	41.0	—	34.5	40.0	43.6	24.3

TABLE 2—GRATE ASH AND FLY ASH SAMPLES COLLECTED FROM BOILER NO. 7 OF POWER PLANT, BEFORE IT WAS CHARGED WITH COAL ADMIXED WITH COKE BREEZE

Dates of collection	Nature of Sample	Proximate Analysis, %			
		Moisture	Ash	V.M.	F.C.
2.6.1965	Grate-ash	0.3	78.7	0.6	20.4
	Fly-ash	0.6	42.7	1.6	55.1
3.6.1965	Grate-ash	0.4	74.1	0.4	25.1
	Fly-ash	0.4	47.6	1.0	51.0

analysed (Table 4). It is seen that on an average 20 per cent of combustible is carried over with grate ash and 53 per cent with fly ash.

Table 3 shows the analysis of the samples collected during test period. It shows the percentage of combustible matter carried over with grate ash being 24 per cent and that with fly ash being 50 per cent. This is an average of the last three days of test run of boiler No. 7. The results of the first two days were not considered as the boiler condition had not been stabilised due to the sudden change over.

Screen analysis of the coke breeze used in blending shows that about 40-50 per cent is below 3 mm.

Discussion

The average content of combustible in grate ash and fly ashes vary, and it is very difficult to get any data which can represent the performance of all the boilers throughout the year. One day's analysis of all the 6 boilers (Nos. 1 to 6; Table 4) showed 20 and 53 per cent combustible matter in the grate ash and fly ashes respectively, but just before the trial run the boiler No. 7 showed 24 and 55 per cent combustible in the grate and fly ashes respectively.

The first two days test run in boiler No. 7 gave erratic results but more uniform results were obtained for the

TABLE 3—GRATE-ASH, FLY-ASH, COAL AND COAL ADMIXED WITH COKE BREEZE SAMPLES COLLECTED FROM POWER PLANT (BOILER No. 7) AFTER THE BOILER WAS CHARGED WITH COAL & COKE BREEZE

Date of Collection	Nature of Sample	Proximate Analysis, %				Screen Analysis Coke Breeze Used (-3 mm.)	Remarks
		Moisture	Ash	V.M.	F.C.		
14.6.'65	(a) Coal	0.6	23.1	21.1	55.3	50%	Results seem to be erratic, condition probably unstable.
	(b) Coal & Breeze	0.95	22.94	17.9	58.2		
	(c) Grate-ash	0.2	69.1	0.9	29.8		
	(d) Fly-ash	0.5	48.5	1.2	49.8		
15.6.'65	(a) Coal	0.7	22.9	19.2	57.2	43%	
	(b) Coal & Breeze	0.9	26.3	17.7	55.1		
	(c) Grate-ash	0.2	68.5	0.7	30.6		
	(d) Fly-ash	0.5	42.3	1.2	56.0		
16.6.'65	(a) Coal	0.5	25.5	18.8	55.2	44%	
	(b) Coal & Breeze	1.0	25.0	17.5	55.5		
	(c) Grate-ash	0.5	73.3	0.7	25.5		
	(d) Fly-ash	0.5	50.6	1.2	47.7		
17.6.'65	(a) Coal	0.8	22.0	19.7	57.5	35%	
	(b) Coal & Breeze	1.0	24.5	17.5	57.0		
	(c) Grate-ash	0.2	78.7	0.9	20.2		
	(d) Fly-ash	0.8	50.0	1.2	48.0		
18.6.'65	(a) Coal	0.7	24.2	18.4	56.7	48%	
	(b) Coal & Breeze	1.0	23.9	19.1	56.0		
	(c) Grate-ash	0.2	76.1	0.9	22.8		
	(d) Fly-ash	0.9	48.9	1.0	49.2		

last three days, when the amount of combustibles was on an average 24 and 50 per cent in the grate and fly ashes respectively, which seems even better than when this boiler was run with coal alone just before the test run.

Even when compared with the average performance of boilers when the combustible matter was 20 and 53 per cent in grate and fly ashes respectively, the performance during the trial with coke breeze mixture was quite satisfactory. The relative combustion efficiency of the boilers as calculated are shown below (Tables 5, 5A and 6).

There were criticisms on the use of breeze (of below 7 mm. size) in boilers from the point of view that the fine particles being lighter in weight would be taken along with the flue gas causing considerable wear on the vanes of the I.D. fans. Due to their low volatile matter content the ignition temperature of fines is high and the initial burning is difficult. The efficiency would also be proportionately low as much of breeze would escape

TABLE 4—GRATE & FLY-ASH SAMPLES COLLECTED FROM DIFFERENT BOILERS OF POWER PLANT ON 22.6.65

Boiler No.	Nature of Sample	Proximate Analysis, %			
		Moisture	Ash	V.M.	F.C.
1	Grate-ash	0.5	79.5	1.1	18.9
	Fly-ash	1.2	52.9	1.9	44.0
2	Grate-ash	0.3	81.7	0.6	17.4
	Fly-ash	1.9	40.1	3.8	54.2
3	Grate-ash	0.2	86.6	1.1	12.1
	Fly-ash	0.9	50.4	1.3	47.4
4	Grate-ash	0.2	78.5	1.8	19.5
	Fly-ash	1.1	50.4	1.6	46.9
5	Grate-ash	0.3	82.5	0.9	16.3
	Fly-ash	0.5	40.9	1.4	57.2
6	Grate-ash	0.5	73.8	0.8	24.9
	Fly-ash	0.6	48.2	1.8	49.4

burning. But our experiments on the use of 6 per cent breeze of size range 3-7 mm. (and containing approximately 50 per cent below 3 mm. due to inefficiency of screening) show that the combustible content of the fly ash has not increased indicating thereby that coke fines have not escaped during combustion. Similarly, the combustible matter of the grate ash was found not to increase.

The fine breeze has a very abrasive action on steel plates and causes a lot of wear on chute and hopper of coal handling plant. Concrete bunkers and hoppers may offer better resistance to abrasion. Manganese steel is a better solution than ordinary steel.

Erosion trouble with the boiler tube is very common. The liability of this kind of trouble to occur depends probably more on the abrasive nature of the coke breeze than on the coal. It is not known with certainty how much extra trouble due to clinker formation would accentuate from the use of only 6 per cent breeze along with coal.

Conclusion

The above results, based on the combustible matter of grate and fly ashes before and during the test run, show that coke breeze can be used in a boiler (using only coal) to the extent of 6 per cent without much loss of efficiency. As the quantity of grate and fly ashes during the trial run could not be obtained for the particular boiler (No. 7), the results are only approximate. The effect of breeze on the erosion of boiler tubes

TABLE 5—PERFORMANCE DURING NORMAL OPERATION OF POWER PLANT WITHOUT COKE BREEZE
(for the Boilers Nos. 1-6 for one day)

	Ash, %	Moisture, %	Combustible, %
Coal	24	0.7	75.3
Grate ash	80	—	20.0
Fly ash	47	1.0	52.0

For 200 tons/day feed of coal per boiler.

Average grate ash quantity	= 50 tons/day
Average fly ash quantity	= 20 tons/day
Qty. combustible in coal-feed	= 150.6 tons/day
Qty. combustible in grate ash	= 10 tons/day
Qty. combustible in fly ash	= 10.4 tons/day
Total combustible	= 20.4 tons/day
Percentage of combustible burnt	= $\frac{150.6-20.4}{150.6} \times 100$ = 86.4%

TABLE 5A—PERFORMANCE OF OPERATION OF BOILER No. 7 WITH COAL ALONE BEFORE THE TEST RUN

	Ash, %	Moisture, %	Combustible, %
Coal	24	0.7	75.3
Grate ash	76	—	24.0
Fly ash	45	0.5	54.5

For 200 tons/day feed of coal.

Average grate ash quantity	= 50 tons/day
Average fly ash quantity	= 20 tons/day
Quantity of combustible in coal feed	= 150.6 tons/day
Quantity of combustible in grate ash	= 12.0 tons/day
Quantity of combustible in fly ash	= 10.9 tons/day
Total combustible	= 22.9 tons/day
Percentage combustible burnt	= $\frac{150.6-22.9}{150.6} \times 100$ = 84.8%

TABLE 6—TRIAL OPERATION OF BOILER No. 7 WITH COAL & COKE BREEZE (6%) MIXTURE

	Ash, %	Moisture, %	Combustible, %
Coal and coke-breeze mixture	24.5	1.0	74.5
Grate ash	76.0	—	24.0
Fly ash	49.8	0.7	49.5

Assuming the quantity of grate ash and fly ash to be same as in the average boiler operation.

Quantity of feed of coal and coke breeze	= 200 tons/day
Average grate ash quantity	= 50 tons/day
Average fly ash quantity	= 20 tons/day
Quantity of combustible in Feed (Coal 94%+coke breeze 6%)	= 149 tons/day
Quantity of combustible in grate ash	= 12 tons/day
Quantity of combustible in fly ash	= 9.9 tons/day
Total combustible	= 21.9 tons/day
Percentage of combustible burnt	= $\frac{149-21.9}{149} \times 100$ = 85.3%

On the basis of performance run of the Boiler No. 7 with coal alone assuming the quantity of grate ash and fly ash remaining the same i.e. 50 and 20 tons per day respectively, the combustion efficiency of coke breeze is as follows:

$$\text{Coke breeze combustion efficiency} = \frac{85.3 - (84.8 \times 0.94)}{.06} = 93.3\%$$

is not possible to know from a trial run of very short period. The authors would like to have the trial extended for all the boilers for a longer period during which time the quantity and quality of grate ash, fly ash as well as feed of coal and breeze could be definitely ascertained.

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Notes & News

Micronutrients Mixed with Liquid Fertilizers

The problem of micronutrients to be mixed with liquid fertilizers is their low solubility and thus a high content of micronutrients is not possible if the product is to be made free from solids. By using the new chelated forms of micronutrients in liquid fertilizers satisfactory results are obtained. Liquid fertilizers mixed with micronutrients and containing herbicide and insecticide have some advantages over solid fertilizers. According to H. E. Ulmer, Research Department, Allied Chemical Corp.'s Agricultural Division using the trace element deficiencies and assuming an average 500 lbs per acre fertilizer applications the following generalizations of liquid fertilizers mixed with micronutrients are possible: (1) The urea ammonium nitrate, ammonium nitrate and ammonium polyphosphate solutions are capable of containing sufficient individual micronutrients in solution to correct severe molybdenum and boron deficiencies, slight to moderate deficiencies of copper iron and zinc and slight manganese deficiencies. (2) Aqua ammonia (30%) is capable of correcting severe zinc boron and molybdenum deficiencies. (3) Complete N-P-K fertilizers in the polyphosphate system can potentially correct slight to somewhat better than moderate trace element deficiencies. (4) In orthophosphate fertilizers, boron and molybdenum deficiencies may be corrected in solution, but even slight deficiencies in the other trace elements must be corrected by the use of appropriate organic metal chelate or complex.

The use of suspensions allows the correction of moderate to severe deficiencies of all the trace elements. With polyphosphates coming into greater use, the future of the addition of micronutrients in liquid fertilizers looks bright.

[Farm Chemicals, 113(2) (1967), 68]

New Nitrophosphate Process

Stamicarbon N.V. subsidiary of Dutch State Mines has developed a process

which yields high-analysis NP and NPK products, in which only phosphoric and nitric acids, ammonia and potash salts are used. Typical products are 24-24-0, 17-17-17 and 22-11-11. The investment cost of the plant is minimal but the cost of the product may be high because of the high price of the phosphoric acid required. The relative water-solubility can be 95% for the standard wet process phosphoric acid and up to about 100% if thermal phosphoric acid is used.

Because of the increasing cost of sulphur and consequently of sulphuric and phosphoric acids, Stamicarbon has developed yet another process that disposes with the use of phosphoric and/or sulphuric acid and yet yields products with a high P_2O_5 water solubility. The economics of the conventional Odda process at increased crystallization rates would be unattractive, and there is also a limit to the possibility of obtaining more calcium nitrate by cooling beyond a certain temperature, while the increased output of calcium nitrate per ton of NP constitutes a further problem. Hence Stamicarbon's development is a third alternative process.

Phosphate rock is dissolved in 55-60% HNO_3 and a 40% solution of ammonium sulphate is added to the acid solution in order to precipitate calcium sulphate, which is carried out in two stages to obtain a precipitate for easy filtration. Calcium sulphate obtained as a byproduct can be converted to a 40% ammonium sulphate solution in separate plant unit, using ammonia and carbon dioxide for conversion.

After filtration, the acid liquid obtained is further neutralized and the neutralization is automatically controlled by pH. The neutralized product is concentrated by evaporation to a final moisture content of 1% in the case of NP and 1.5% in the case of NPK products which are subjected to prilling in a prilling tower where desired quantity of potassium salt is added. The important feature of the new process is that nitrogen is removed from the acid solution as in the Odda process, but by

lowering $CaO:P_2O_5$ ratio to the degree required, extra nitrogen is added to the process. A good average NP formula is 25-15-0. If it is required to make an 1:1 product, this can be done by adding phosphoric acid after the dissolution stage, thereby producing a 21-21-0. The main merit of the new process, however, is the possibility of producing NPK products without the use of sulphuric or phosphoric acid and NP product with 60% P_2O_5 water-solubility.

[Phosphorus and Potassium, 26 (1966), p. 24]

New Technology for Cleaning Wet-process Phosphoric Acid

A new process for cleaning phosphoric acid manufactured by wet process has been developed by Israel Mining Industries (IMI), Haifa, Israel.

The principle of the process, which consists of two single steps, is based on the characteristics of certain organic solvents to extract phosphoric acid selectively, leaving precipitate forming impurities in the residual aqueous phase, together with some quantity of phosphoric acid. Recovery of the clean acid from the extract is achieved by utilizing solubility differences as a function of temperature. Solvents preferred by IMI are esters and ethers, particularly ethers with two or five carbon atoms in each radical. Extraction of phosphoric acid is made at one temperature and released from the solvent at a higher temperature. Two acid streams are obtained, one of the cleaned acid and the other of the residual acid. The total P_2O_5 input is recovered in these two streams. The split of clean acid, which will range between 50-70% and its composition will depend on the composition of the feed acid and its concentration. The residual acid will be obtained at nearly the original concentration and can be concentrated further to 69% P_2O_5 which is nearly 100% orthophosphoric acid without scale formation.

[Phosphorus and Potassium, 25 (1966), 30]

Granulation of Potassium Salts

Fisons Fertilizer Ltd. has developed a technique of granulating potassium salts satisfactorily by forming a mixture with ammonium nitrate and/or urea and tumbling or agitating the mixture. Little or no water is required in the processing, the fluid being supplied by the ammonium nitrate and/or urea which should be present in amounts sufficient to provide an adequate fluid phase for granulation at the temperature at which the process is operated. Lower temperatures may be used by including small amounts of water in the mixture. Preferably the ammonium nitrate and/or urea should be present in eutectic proportions of 59 : 41 parts by weight when it is possible to perform the granulation at temperatures as low as 45°C. Optionally with addition of little water the ratio of the mixture becomes 54 : 47 : 7. The mixture may be formed by spraying molten ammonium nitrate and/or urea at a temperature of around 80°C on the potassium salt in the conditioner comprising a rotating drum. From the conditioner the mixture passes to another rotating drum where the product is cooled. A rotating cylindrical drum is used to tumble the mixture which is heated by passing a stream of hot air or gases through the rotating drum. The temperature of the air or gases at the inlet end is in the range 190-220°C reducing to about 100-120°C on leaving the drum. The temperature of the granules leaving the drum is of the order of 50-110°C. 75-80 per cent of the total granulated product may be recycled.

[Phosphorus and Potassium, 25 (1966), 45]

Diammonium Phosphate—Latest Process

A new fertilizer complex has been recently built at Kerens (Texas) to manufacture a product with analysis of 18-46-0. The raw materials used are liquid anhydrous ammonia, 42 per cent wet process phosphoric acid and 93 per cent sulphuric acid.

Phosphoric acid is metered to the plant and most of it is introduced to the scrubber system. The water required to maintain the process balance is fed to the scrubber system and the resulting diluted acid is circulated through two scrubber systems to recover ammonia and dust losses from the process.

Phosphoric acid, scrubber liquor, sul-

phuric acid and part of the ammonia required are continuously added to the reactor. The slurry, manufactured in the reactor, is continuously transferred under controlled conditions to a rotary ammoniator where the balance of anhydrous ammonia required is added. A circulating load of product, ground oversize and fines, is fed to the ammoniator so as to provide the proper ammoniating and granulating conditions. The material that is discharged from the ammoniator passes through a rotary dryer where the moisture content is reduced to approximately 1 per cent. Dried material is elevated and screened. The oversize removed by the screens is ground in cage mills and returned to conveyor system for reprocessing in the ammoniator.

All the air and other gases exhausted pass through scrubbing equipment which recovers the ammonia and dust and these are fed with the circulating phosphoric acid stream to the reactor and reprocessed.

[Fertilizer and Feeding Stuffs Journal, 63(2) (1966), 43]

Potassium Nitrate as a Fertilizer

Potassium nitrate's agronomic advantages due to high analysis (13-0-44), greater plant response with nitrate form of nitrogen and almost complete absence of sodium chloride or other substances (which can be deleterious to crops) has made it an important and popular fertilizer.

Direct application of potassium nitrate in prilled form has been widely used on tobacco, tomatoes, leafy vegetables, citrus and other fruits. Benefits of using potassium nitrate in granulating mixed fertilizers are increased productivity capacity, harder and better shaped granules, reduced hygroscopicity and improved storage characteristics.

Addition of potassium nitrate to ammonium nitrate stabilizes it, transition temperature of ammonium nitrate is lowered, the expansion factor is decreased, the hygroscopicity is reduced making improved storage facility. Liquid fertilizers containing potash as well as nitrogen, phosphates and other nutrients are becoming more widely used. Potassium nitrate can be used to advantage in mixtures with high N to K₂O ratios such as 24-0-7 with urea. Further uses of potassium nitrate in liquid as well as suspension and slurry fertilizers are being developed. Complex solid fertilizers such as 17-17-17 and 23-11-11 have been prepared on a pilot prilling column using a molten mix-

ture of ammonium nitrate, monoammonium phosphate and potassium nitrate. The material is hard, dense and uniform in size with good hygroscopic properties.

[Robert J. Harvey, Phosphorus and Potassium 25 (1966), 41]

Single Tank Circular Reactor Boosts Phosphoric Acid Yields

Emphasis in phosphoric acid engineering, which so long centred on improving the acid filters, has shifted to the reaction system. Probably the most unusual phosphoric acid reactor is Dorr-Oliver Inc's large circular tank with a smaller concentric tank in the centre, used by the American Agriculture Corp'n. (AAC) fertilizer complex.

In the AAC reactor made of steel, phosphate rock from the filters and 94 per cent H₂SO₄ enter the tank in the annulus section where the major portion of the reaction takes place. Retention time in the annulus is about 8 hours. This is nearly nine times that in centre section which has two functions: to eliminate short circuiting of rock and to reduce supersaturation in the liquid phase. Six agitators in the annulus along with carefully positioned baffles also help to minimize short circuiting and also provides the optimum combination of slurry flow and turbulence.

Reacted slurry flows by gravity from the annulus into the centre section through an opening in the bottom of the inner wall. From the centre compartment, slurry flows via a launder, an open pipe, to the filter feed tank, and then to remainder of the process. Considerable amount of heat is removed from the reactor due to highly exothermic digestion of phosphate rock.

It is estimated that the ultimate recovery potential in their angular reactor, when used in a conventional dehydrate process, is 97.5 per cent of the P₂O₅ fed. It is felt that the highest recovery rate is possible with a multi-tank or compartmented tank reaction system would be 96.5 per cent. The extra recovery as compared to plants having conventional reactors would give 50 percent/ton for P₂O₅. The reason for this improved conversion is that a uniform high sulphate level is easy to maintain in the reactor. Because of the large capacity of the reactor, feed variations are buffered. These variations—a problem in other reactors—in turn cause solid solution losses.

Configuration of the reactor consider-

ably reduces the power required to agitate the digestion slurry. Also, the annular compartment helps collapse the foam which reduces the amount of antifoam reagent that must be added. The reactor is a simple vessel with few costly partitions. It can be located outdoor and can withstand fairly severe climates. One operator and an assistant can handle a single tank plant, including the filtration and evaporation steps.

[Chemical Engng., Dec. 19, 1966, p. 82]

TVA's Technique for Ammonium Polyphosphate

TVA has been able to develop a two-stage process on a laboratory scale to make solid ammonium polyphosphate fertilizer direct from wet process orthophosphoric acid. It involves partial neutralization of the acid in one vessel, followed by reaction in a second. In earlier work to develop polyphosphate fertilizer, TVA used to ammoniate superphosphoric acid. The new process avoids the use of the concentrated acid.

In this process two reactors are used. Wet-process orthophosphoric acid is fed into the first and ammonia into the second. Off-gases from the second reactor consist mostly of ammonia and steam and these are passed into the first reactor, where the ammonia reacts with the fresh acid to give a partially neutralized material, which is pumped to the second reactor where the final ammoniation takes place and a portion of the orthophosphate dehydrates to polyphosphate. The product is discharged from the bottom of the second reactor as a melt. A hard granular product is produced by feeding the melt into a pug mill together with the recycled fines. Grades produced by TVA are 12-57-0, 11-66-0, 12-59-0 and 11-63-0. To avoid the melt solidifying in the second reactor before it can be discharged, the feed acid is preheated; strip heaters have been used on the reactors. In a typical operation, acid is preheated to 250°F before it is fed to the first reactor. Ammoniation to a pH of 1.9 in this reactor raises the temperature to 310°F. The second stage reactor is kept at 475°F by strip heaters to obtain a product with at least half of its phosphate as polyphosphate. The 11-61-0 material is produced with 55% of its P_2O_5 and compares well with about 1,500 B.t.u. required to concentrate orthophosphoric acid to superphosphoric acid, used previously, in producing ammonium polyphosphate.

All the phosphate in the formulations produced by the new process is in an available form when the acid used does not contain more than about 2% Al_2O_3 and Fe_2O_3 . If these impurities exceed the 2% level, availability can fall as low as 88% because of the formation of aluminium pyrophosphates.

[Phosphorus & Potassium No. 24, Aug/Sept. 1966, p. 30]

Cleaning Cracked Gases

Before separating ethylene and acetylene from cracked hydrocarbons it is advisable to remove impurities, which are very soluble in solvents, for acetylene and ethylene. Such impurities can be removed successfully by feeding the gas stream to the bottom of an absorption tower.

Initially the gases are brought into contact with the solvent, which flows downwards from the middle of the tower. In this section the solvent contains impurities at unsaturated concentrations. The gases then come into contact with uncontaminated solvent flowing down from the top section. The contaminated solvent is then fed from the bottom of the absorption tower to the top of a concentration tower where it is heated whilst flowing downwards. Useful gases are released from the top of the concentrating tower, while other impurities dissolved in the solvent are retained.

The solvent containing the impurity leaves the bottom of the concentration tower and is fed to the top of the first of two stripping towers where it is heated as it flows downwards. Most of the impurity is discharged from the top of the first stripping tower. Most of the solvent leaving the bottom of the first stripping tower is fed to the middle of the absorption tower, while the remainder is fed to the top of a second stripping tower, and is heated as it flows downward.

In this way the impurities in the solvent are discharged from the top of the second tower, while the purified solvent leaving the bottom is recycled to the top of the absorption tower.

[ECN, 11(262) (1967), 40]

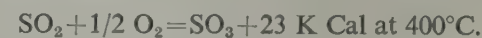
Sulphuric Acid from Sulphide Ores

Sulphide ores, e.g. pyrites (FeS_2), pyrrhotite (about $Fe_{11}S_{12}$), zinc blend (ZnS), copper pyrites ($FeCuS_2$) have first to be roasted to render them smelttable. The roaster gas obtained is the cheapest raw material for the manufacture of sulphuric

acid which can be recovered as follows: (1) dedusting of the roaster gas; (2) cooling and purification of the gas; (3) drying of the gas; (4) drying of air for direct cooling; (5) catalytic oxidation of the sulphur dioxide and (6) absorption of the sulphur trioxide and conversion to sulphuric acid.

Multi-hearth roasters have proved valuable when roasting nonferrous metal and arsenical pyrites since they provide cinders suitable for leaching and contain less than 0.06 per cent As. Also in these roasters, ores of all granulation from the fine gravel of 6-8 mm. can be roasted without dust removal problems. Multi-hearth roaster provides a steam yield of 80 per cent of that of fusolid roasters. In the Zieren-Chemiebau multi-hearth roaster 90 to 100 per cent of the cooled gas is recycled and air is injected to augment the specific gravity to 135-145 tonnes S/m^3h . Roasters of 6.5 to 7 metres diameter, with one drying hearth and 8 to 13 roasting hearths, can treat daily 40 to 100 tonnes of pyrites containing 48 per cent S. The roaster gas contains 8-9 per cent SO_2 and when the gas is recycled 11 to 12 per cent SO_2 .

Catalytic Oxidation of SO_2 takes place as follows:



thus supplying about 235 K Cal per each Kg. of sulphuric acid produced.

Vanadium pentoxide type catalyst is contained on four trays. Its conversion efficiency of SO_2 to SO_3 is 98 per cent. SO_3 is absorbed in 98.3 per cent H_2SO_4 acid with 99.9 per cent yield.

[Sulphur No. 66, Oct/Nov. 1966, p. 32]

Lecture

Dr. K. R. Chakravorty, General Manager, P. & D. Division, delivered the first of a series of lectures on his newly-propounded theory of the Universal Spherical Wave of the "Energy Field of the Universe and Atom", on March 14, 1967, before a gathering of professors, lecturers, scientists and technologists at the Bihar Institute of Technology, Sindri.

The Chakravorty Law of evolution of the universal wave could be briefly expounded as follows: If something would evolve out of nothing, which would subsequently establish an equilibrium concept of configuration, there must be a fundamental dimension as Cause creating the evolution. From a state of indefinable fundamental, of infinite intensity and



Dr. J. P. Chowdhary, Director B.I.T., welcoming Dr. Chakravorty, Prof. S. Prasad of Civil Engineering is on the right.

purity, having no configuration, the finite evolution starts, through a state of point of position of fundamental assuming finite highest magnitude associating with least magnitude of derived opposite dimension, assuming 4 directional isotropic probabilities. The fundamental and derived opposite assume regular tetrahedral configuration in association with their containing dimensions. The two, from the state of point of position, undergo variation in their magnitudes in opposite directions in the same configuration till their magnitudes equalises at a state of equality equilibrium, from which state the two equals segregate and continue to vary in their magnitudes in two phases till the magnitude of derived becomes highest and that of fundamental least at a state forming the boundary of the universal wave. Equilibrium configuration of the wave is established due to the action and reaction of magnitudes of intensities of the two opposites, viz. fundamental and derived, (e.g. energy and matter) and magnitudes of size of their containing dimensions (viz. space and time) which are opposite to those of the contained. The four dimensions: 2 opposite pairs of 2 opposites make equilibrium concept of regular tetrahedral configuration of universal wave which is symbolically presented as $+/- = -/+$.

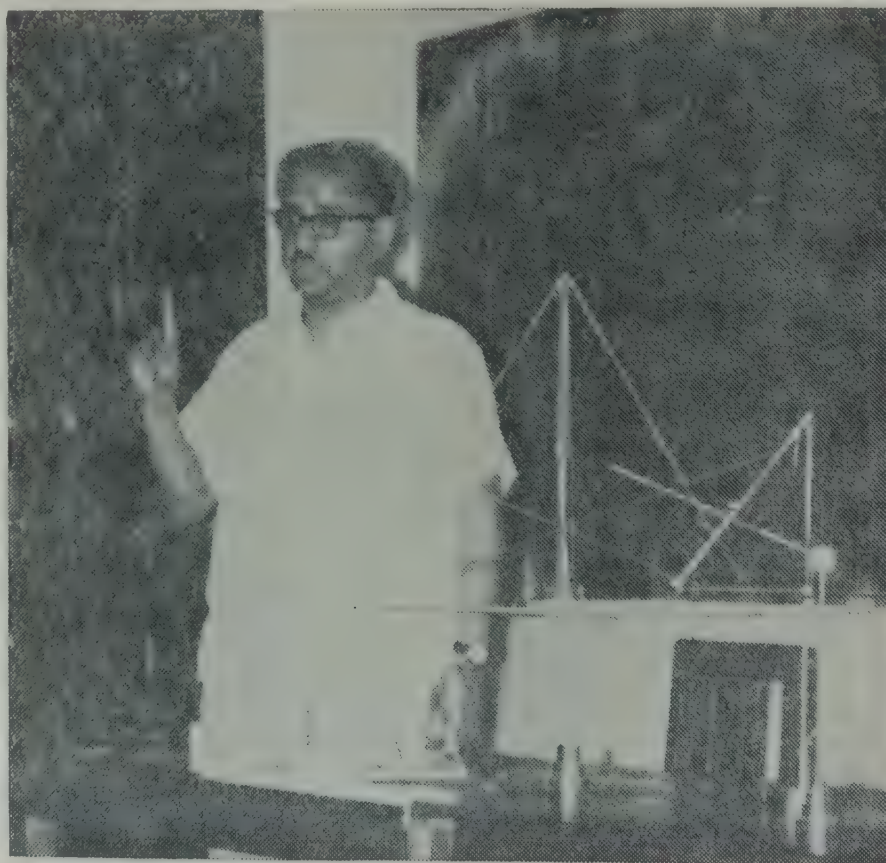
This universal law of evolution has been applied in the finite 4 dimensional

energy, matter, space and time manifestations of the inanimate universe, dimensional equilibrium concept of which has been represented as $E/M = L/T$ or $ET/ML = a \text{ constant}$. Incorporating the

postulates of the theory that space L is radial and 4 directional and time T is orbital and 3 directional, the equilibrium dimensional relationship was expressed as $ET/ML = L^4/T^3$ or $ET^4/ML^5 = \text{equilibrium constant}$. The later has the same dimensional significance as that of the conventional gravitational constant.

The theory, as a single unified concept, was shown to be capable of correlating and explaining the outstanding problems of science, covering the following: Universe of finite concept; gravitational and inertial motions; significance of matter and energy; gravitational fields of the universe—atoms and their magnitudes; correlations of gravitational and magnetic fields and electromagnetic induction. This theory also suggests an expanding (up to a certain maximum critical size) and oscillatory universe against the static state theory of universe by F. Hoyle.

Dr. Chakravorty has also revived the Huygen's Ether Concept by stating "The Universal Space is field of force due to energy". In his own words—"the inanimate universe in this theory consists of four dimensions, energy, matter, space and time. The energy creates space and matter occupies position in space describing time. The evolution of the universal



Dr. Chakravorty explaining some important points.

field occurs through space assuming tetrahedral configuration leading to the manifestation of the universe as the spherical wave of energy and matter. Space in the configuration is radial and time is orbital. Highest magnitudes of intensities of energy and matter determine the centre and the boundary respectively of the spherical wave establishing their respective potential

gradients in between. Space field covered within the spherical wave is full of energy as force like ether but having gradient intensity of space as force between the centre and the boundary. Energy is intensity of space and matter intensity of time. The difference between ether and space of this theory as energy field lies in that the space field is not filled with any

ether-like fluid but space itself is energy". He has also shown why "ether" could not be detected in the famous Michelson-Morley experiment.

The lecture continued for more than three hours. At its conclusion, Dr. J. P. Chowdhary, Director of the B.I.T., proposed the vote of thanks.

News in Brief

Phosphoric Acid From Bones

Tricalcium phosphate can be extracted from bones by an economic process which achieves a 100 per cent conversion to phosphoric acid. This in turn allows phosphates to be produced in high purity and good yield

First the bones are reacted with between 80 and 150 g/l. phosphoric acid at 20°C, to produce mono-calcium phosphate, which is then treated with sulphuric acid and the precipitated calcium sulphate is removed.

Part of the mono-calcium phosphate is then passed over a cation exchange resin in the acid form to produce phosphoric acid and free it of cationic impurity.

[ECN, 11 (264), (1967), 40]

Making NH_4NO_3 Solution

Concentrated solution produced by the reaction of ammonia with nitric acid is obtained in good yield by cooling the process stream, before finally concentrating it. Process steam is produced in useful quantities during cooling.

To obtain an 83 per cent concentration, the aqueous acid is reacted with ammonia vapour at between 135° and 175°C and at a pressure of from 10 to 100 lb/in² gauge. After cooling by heat exchange with water, the temperature of the product stream is dropped to between 120° and 150°C and the water is vaporized to form process steam at a pressure of from 10 to 30 lb/in² gauge.

Dilute ammonium nitrate solution is heated further to a final temperature in the range of 135 to 165°C by heat exchange with the reacting nitric acid and ammonia. This vaporizes part of the water to form steam at 5 to 20 lb/in² gauge, the concentrated ammonium nitrate solution containing less than 20 per cent water.

[ECN, 11 (264), (1967), 40]

Nitric Phosphates

According to the studies made by the T.V.A., Odda process (which uses no

sulphuric or phosphoric acids and in which calcium nitrate is separated by crystallization and filtration) gives the lowest cost per unit of plant food compared to processes requiring phosphoric and/or sulphuric acids. Inclusion of an ammonium sulphate recycle to remove the remaining calcium yields a water soluble 28-14-0 product.

The presence of iron and aluminium compounds in wet process phosphoric acid often causes the formation of citrate insoluble phosphates, when the acid is subjected to high temperatures, as in superphosphoric acid and ammonium poly-phosphate manufacture. For reducing iron and aluminium impurities, TVA has developed a method by adding potassium sulphate to form a citrate-soluble precipitate $(\text{Fe, Al})_3, \text{KH}_{14}(\text{PO}_4)_4 \cdot 4 \text{H}_2\text{O}$ which can be removed by decantation or filtration. This was demonstrated by a small continuous unit which removed about half of the iron present and a little of the aluminium to give a product acid containing about 1% Fe_2O_3 , 1% Al_2O_3 and 53% P_2O_5 . About 33% of the P_2O_5 in the feed acid may appear in the precipitated sludge, but as this is citrate soluble, it can be recovered for further processing into a fertilizer.

[Brit. Chem. Engng., 12(2) (1967), 232]

Ammonium Sulphate Nitrate

Low melting point mixtures of ammonium nitrate and ammonium bisulphate and possibly ammonium sulphate may readily be formed into granules and simultaneously ammoniated to produce ammonium sulphate nitrate. The molten mixtures of the components are granulated by running it on to a cooled surface, preferably by spraying it on to a ground base in a rotating drum. Ammonium sulphate nitrate can then be recovered. The temperature of the base material in the drum is kept at between 60° and 90°C. The ratio of ammonium nitrate to ammonium bisulphate in the molten mix is put at between 1 : 1 and 2.2 : 1. Up to

16 per cent ammonium sulphate can be incorporated in the mix.

[ECN, 11(259) (1967), 34]

Ammonia Synthesis Gas

In a new process for making synthesis gas, the hydrogen is prepared by cracking hydrocarbons in the presence of oxygen and subsequently is contacted with liquid nitrogen. The process can be operated successfully using two rectification columns for liquefying and rectifying air to provide the nitrogen, the columns being operated under reduced pressure and in thermal contact with one another. The arrangement allows a first portion of gaseous nitrogen at the head of the first rectification column (at high pressure) to be condensed by heat exchange with a liquid having a high free oxygen content which is separated in the second rectification column, the latter operating at a lower pressure. Efficiency can be improved further by condensing part of a second portion of gaseous nitrogen which separates at the head of the first column, by heat exchange with liquid nitrogen which has been brought into contact with part of the hydrogen. The condensed nitrogen can then be rectified. Part of the liquid nitrogen which has been brought into contact with the hydrogen is obtained by liquefying pure gaseous nitrogen by heat exchange with part of the liquid having a high free oxygen content, which is separated at the bottom of the second column.

[ECN, 11(260) (1967), 34]

Concentrating H_3PO_4

Contrary to other methods of concentrating phosphoric acid, this new method is aimed at minimizing the amount of phosphorous pentoxide distilled from wet process acid, the concentrated and purified acid being recovered from a phosphorous pentoxide aerosol.

Minimizing the phosphorous pentoxide content in this way has the effect of increasing the amount of product recovered

from the aerosol, since the product is comparatively pure as well as being concentrated. Therefore, it can be used for many purposes, for which normally thermal acid is suitable.

The acid is concentrated by contacting dilute acid with gaseous combustion products at a temperature high enough to cause phosphorous pentoxide to vaporize. This produces an aerosol containing a suspension of phosphorous pentoxide particles in a gaseous phase of combustion products, water vapour and impurity.

Subsequently, the aerosol is separated from the dilute acid and after the particles coalesce to produce acid they may be separated from the gas phase at a temperature which maintains the concentration of phosphorous pentoxide greater than 50 per cent. This temperature should also be high enough (about 150°C) to prevent volatile impurities condensing. The bulk acid temperature in the distillation vessel is in the range 400 to 500°C, but that between the distillation zone and the cold scrubber should be maintained between 150° and 250°C.

(British Patent 1050813, Albright and Wilson Ltd., U.K.).

[ECN, 11(261) (1967), 38]

Phosphatic Fertilizer From Basic Slag, Hydrochloric Acid and Rock Phosphate

Investigations by Dr. M. Shafik, Managing Director and A. Shabrey of Societe Financiere et Industrielle d'Egypte, on laboratory scale showed that it is possible to convert the citric acid-soluble P_2O_5 in to 23% citrate-soluble P_2O_5 . A higher efficiency phosphatic fertilizer from basic slag, by the application of hydrochloric acid and rock phosphate is also possible. Preparation of dicalcium phosphate involves the following steps: (1) Treatment of rock phosphate with hydrochloric acid to obtain a solution of phosphoric acid; (2) Filtration of this solution and neutralization with lime or limestone until dicalcium phosphate precipitates; and (3) Filtration, washing and drying the product. The fertilizer obtained is acceptable to farmers at reasonable price.

[Phosphorous and Potassium, 28 (1966), 27]

Highly Concentrated Superphosphoric Acid

Occidental Agricultural Chemicals Corp. (Oxychem.) has developed a highly concentrated superphosphoric acid (72-76%

P_2O_5) containing 65% polyphosphates using the Nordac-Occidental Process. Oxychem's superphosphoric acid is also claimed to have the highest P_2O_5 fluorine ratio of any commercial superphosphoric acid made from wet process acid. Hence, it can be used as a mineral supplement to animal feeds. It is also employed in liquid fertilizers being easily processed into nitrogen phosphate combinations. In production of solid fertilizer, the new acid is reported to offer advantages such as low water content, uniformly in product and production of higher analysis fertilizers than are presently available. Agronomic advantages claimed for this high polyphosphate acid are that when it enters the soil it sequesters micronutrient elements in the soil, thereby making these elements more available to the growing plant. Also there is less rapid fixation of phosphate by calcium, iron and aluminium compounds.

[Phosphorous and Potassium, 25 (1966), 23]

Effectiveness of Dung and Mineral Fertilizers

Systematic application of NPK (NH_4NO_3 , super and KCl), dung and dung+NPK to a 7-course rotation on cultivated sandy light loam increased the number of micro-organisms decomposing organic matter and mobilizing N, dung being more effective than NPK. Dung also increased the number of water-soluble aggregates and the non-capillary porosity under oats. Dung increased the humus and N contents of the mobile aluminium content of the soil somewhat, but these changes did not decrease crop yield. Systematic applications increased the percentage contents of N, P and K in the crops. Maximum yields were produced by applying 20 tons per hectare of dung to rye and potatoes and NPK to rye, flax, potatoes and spring wheat. Mineral fertilizers supplying amounts of N, P and K equivalent to the amounts of these nutrients in dung were easier to use and more economic than dung. Dung increased the potential fertility of the soil more than NPK did. The crops utilized 83 per cent of the N, 59 per cent of the P and 66 per cent of the K supplied by NPK and 55 per cent of the N, 38 per cent of the P and 46 per cent of the K supplied by an equivalent amount of dung.

[Agrokhimiya, No. 11 : 117-23; Abst. Soils and Fertilizers, Vol. 29(4), 1966: Abst. No. 2736]

SAI Process for Concentrating Phosphoric Acid

Sulphuric acid of over 90% H_2SO_4 concentration can be employed to remove water from aqueous phosphoric acid produced by the wet process reports Scottish Agriculture Industries Ltd. The sulphuric acid absorbs water and the heat generated is transferred to the phosphoric acid to raise its water vapour pressure. The aqueous sulphuric acid is used for removing water vapour from above the phosphoric acid, the heat generated in the desiccant being returned to the phosphoric acid. In practice a mass transfer of water from a film of aqueous phosphoric acid to a gaseous medium takes place simultaneously with a mass transfer of water from the gaseous medium to a film of sulphuric acid. The resulting concentrated film of phosphoric acid is returned to the aqueous phosphoric acid, from which fresh films are repeatedly formed, and concentrated, until the desired degree of concentration is achieved, while the resulting hydrated film of desiccant is returned to the aqueous sulphuric acid from which fresh films are formed repeatedly. The sulphuric acid is introduced at 20°C and leaves at 89°C. Phosphoric acid solution enters at 70°C and leaves at 72°C.

[Phosphorous and Potassium, Oct/Nov. 25 (1966), 45]

Developments of Granular Urea-Ammonium Phosphate Fertilizers

World production of urea has increased rapidly in recent years and DAP (Diammonium Phosphate) production has increased spectacularly since 1960. A combination of these developed processes is an attractive route for formulating high-analysis granular fertilizers. Pilot-plant development work was undertaken by T.V.A. to determine the simplest and most economical means for combining urea and ammonium phosphate to produce grades such as 29-29-0, 25-35-0, 34-17-0 and 20-20-20.

A conventional preneutralizer and rotary drum was used to produce the ammonium phosphate component from wet-process phosphoric acid and ammonia. Urea was fed to the process as solutions that would be available from conventional urea synthesis plants or as solid products. Recycle ratios in the pilot-plant operation ranged from 3 : 1 to 5 : 1. The products were closely sized and very well rounded granules; drying to moisture content of 0.5 to 1.0% resulted in good storage pro-

perties when conditioned. Study of the drying step was emphasised since this operation is the limiting factor in establishing the production rate for a plant system. Products are being evaluated in agronomic tests in the U.S.A. and several other countries.

[ACS Abstracts, 152nd Meeting, September 1966, Fisons Limited Felixstowe Technical Bulletin No. 28, 1966: 1213/T/661]

Treating Superphosphates for Fertilizer Compounding

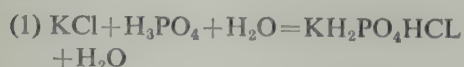
A new technique to produce a finely powdered superphosphate less than 15% above 12 mesh by successively adding 15% urea or ammonium nitrate to the superphosphate to produce a 50/50 mixture has been developed. In this process the mixture is agitated, heated and contacted in a fluidized bed with sulphuric acid at temperatures between 10 and 85°C and in sufficient quantity to convert the mono-calcium phosphate to phosphoric acid.

For optimum results, 80% of the superphosphate should be in the particle size range 12-72 mesh. To produce a suitable product, the superphosphate is washed with acid, followed by three further washes with weaker acid obtained from previous stages, and a final wash with water. The acid liquor produced is mixed with more sulphuric acid and then ammoniated, using anhydrous ammonia, the sludge formed being ultimately incorporated into the fertilizer mixture and granulated. The addition of the sludge to the superphosphate-urea mixture reduces its acidity before drying.

[Phosphorous and Potassium No. 24, Aug/Sept., 1966, p. 47]

Fluidized-Bed Process for Granulated Potassium Metaphosphate

Potassium chloride and orthophosphoric acid are used as raw materials, and the following reaction takes place in two stages:



In this Russian process a solution of the reactants is fed into a fluidized-bed dryer and dispersed with compressed air passing through a spray nozzle. The apparatus is heated by a gas burner, and combustion gases are passed through a mixing chamber and a gas distributing plate with 3%

free urea, to a cylindrical reaction chamber. The temperature of the fluidized-bed is 400-500°C; the fluidizing velocity is 3.5-4.5 m/s; initial heater content in the solution is between 40 and 70% and the final moisture content of the product is 0.02%. The granules which are 2.5 mm. (diameter, size, have a mechanical strength of $225 \times 10^{-4} \text{ N/m}^2$.

[Phosphorous and Potassium No. 24, Aug/Sept., 1966, p. 47]

Mixed Fertilizers by Plate Granulators

A method of making binary mixed fertilizers with N : P ratio of 1 : 1 starting from solutions of ammonium nitrate in water or nitric acid, gaseous ammonia, sulphuric acid and superphosphate has been worked out. The results have been confirmed experimentally and product with an N : P ratio of 13 : 13 and 20 : 20 have been obtained by using a simple and a concentrated superphosphate respectively. The originality of the method consists in the fact that all the main operations i.e. mixture of components, ammoniation, granulation and drying are achieved in a single apparatus the plate granulator.

[British Chemical Engineering, Oct, 1966, p. 242]

Potassium Fertilizer from Steel Slag

A way of making potassium phosphate obtained from the basic slag produced during manufacture of steel for use as a fertilizer is reported by Salzgetter Clerine GmbH, Hannover. Slag is slurried with potassium sulphate for about five hours and the potassium phosphate yield recovered by evaporation. Calcium carbonate is obtained as a by product and excess potassium sulphate is converted into sulphuric acid.

[Science and Technology News letter, High Commission of India, London, Feb. 1967, p. 11]

Recovery of Sulphur from Hydrocarbon Gases

Procel LPD is a new bauxite type catalyst in a pelleted form by which more recovery of elemental sulphur from hydro-carbon gases is possible. It offers the following advantages to sulphur recovery plant designers and operators.

(1) Improved overall sulphur recovery efficiency; (2) Lower operating flow pressure loss; (3) A cleanly sized dust free

catalyst; (4) A catalyst requiring no screening at the converter site; and (5) Having superior carbon burn off characteristics.

The new catalyst is in the cylindrical shape of 5/16 in diam. extrusion-formed is hard and dust free. It is also claimed that the new catalyst minimizes carbon build-up and catalysts carbon burn off. Consequently carbon control is quickly achieved.

[Sulphur, No. 66, Oct/Nov. 1966, p. 37]

New Type SO₃ Catalyst

Lower conversion temperatures for producing SO₃ from SO₂ are claimed for a new catalyst developed by Toyo Koatsu. Conventional vanadium pentoxide catalysts operate effectively at temperatures from 430°C upwards. The new catalyst is stated to give 97% conversion of SO₂ to SO₃ at temperatures 10-20°C below the normal temperature.

[Sulphur No. 66, Oct/Nov. 1966, p. 39]

Making Hydrogen

Hydrogen-rich gas can be obtained from gaseous mixtures containing carbon monoxide and sulphur compounds, by a two-stage conversion process.

First some of the carbon monoxide in the crude mixture is catalytically converted by reaction with water vapour to yield carbon dioxide and hydrogen.

After an intermediary heat-exchange step with the crude stream, the partially converted gas is given a high temperature desulphurization treatment. The remaining carbon monoxide in the desulphurized gas is converted catalytically into carbon dioxide and hydrogen by reaction with water in a low temperature conversion process.

In practice the desulphurized gas is cooled by injecting water into the reaction vessel. Cooling is continued until the starting temperature for the second stage is reached. This produces all the water vapour required for the second stage.

[ECN, 11 (265) (1967), 42]

Producing Acid Phosphate

Dry granular acid phosphate can be produced in a fluid bed reactor by observing certain processing conditions, such as introducing fluidizing gas to the bottom of a bed of particles and introducing acidifying acid.

The fluidized bed is maintained at a

temperature in the range 50° to 375°C and to retain equilibrium conditions the dry acid phosphate containing less than 10 per cent moisture is removed at a rate equal to the rate of addition of phosphate and acid.

The acid is added from above the bed, while some ammonia may be introduced from below. Potassium salt is also added.

Particle size of the phosphate should be about 35 mesh, while the granule size should be in the range 6 to +65 mesh.

Phosphoric acid containing up to 75 per cent solids— P_2O_5 and powdered phosphate—is recommended for the acidification. Not more than 50 per cent of the dry acidified product should be recycled.

[ECN, 11 (263) (1967), 38]

Making Polyphosphate

Low-density polyphosphate can now be manufactured in one step as distinct from the more usual practice of employing a two-stage process. The new method is suitable for making sodium pyro- and tripolyphosphates and involves spray drying a suspension of sodium phosphate solution in the presence of a carbon dioxide yielding solution, for which sodium or ammonium bicarbonates are suitable. In practice, the two liquids are mixed before spray drying, spraying taking place under pressure by passing the mixture through the spray nozzle and through a flame zone. The temperature of the latter is raised sufficiently high to produce off-gases having a temperature of between 280° and 450°C.

When a saturated solution is used for producing carbon dioxide, 0.275 to 6.5 kg. carbon dioxide is required per ton of converted phosphorus pentoxide. For example, when making sodium tripolyphosphate and high phase-I tripolyphosphate, a solution of sodium orthophosphate of P_2O_5/Na_2O molar ratio 3 : 5 is spray dried with 20 per cent sodium carbonate. The off-gases are maintained at temperatures between 380° and 430°C.

[ECN, 11 (261) (1967), 38]

Superphosphate Prices

Based on a study of raw material costs during last quarter of 1966, the ex-works prices of superphosphate (16% P_2O_5) for port factories (factories located within 161 km. of a port), packed in 100 mg. alkathene-lined jute bags have been fixed

from January 1, 1967 at (i) Rs. 272.95 per metric tonne served by ports other than Calcutta, and (ii) Rs. 280.33 per metric tonne served by Calcutta port.

These prices cover 46 per cent of the total number of manufacturing units. In the case of other units, known as 'inland' factories, prices have been fixed after allowing for additional rail freight incurred by them.

[FAI Inf. Serv., 8 (2) (1967), 5]

Spraying Urea on Wheat

The effects of different concentrations of Urea (1-12 per) sprayed at heading and blooming and after blooming on the components of yield, crude and true protein, gluten, calcium, phosphorus and niacin content of wheat have been studied.

Foliar spraying of urea caused an increase in the number of kernels per head and 1000 kernel weight. Concentrations beyond 3 per cent eliminated mottling in grains altogether. Mottling is inversely proportional to protein content. Concentrations from 1 to 6 per cent increased the yield of grain irrespective of season. The yield response was linear when spray was given at heading, an increase of 52 lbs/acre having been recorded with each increase of 1 per cent in concentration, the maximum increase being of the order of 24 per cent. Subsequent sprays were not beneficial.

Urea sprays increased the proportion of grain in total dry matter produced. Increase in total protein content, varying from 18 to 34 per cent, was largely due to that in the true protein fraction. Increases in protein yield per acre are due to N sprays ranged from 24 to 60 per cent.

[FAI Abstr. Serv., 5 (7-9) (1966), 13]

High-Nitrogen Fertilizer for Tropical Countries

A new ultra-high concentration nitrogen compound fertilizer, developed by a British firm, is claimed to be suitable for tropical countries, where rapid exhaustion of soil nitrogen is an inherent risk because of the growing of many crops.

Known as High-N 62, the fertilizer, which has a 25 : 10 : 10 ratio, is specifically intended for grass-land management and continuous cereal growing. The fertilizer, which is in granular form, has storage and drilling qualities equal to the best existing high-nitrogen products. To

overcome the losses in N to which a compound fertilizer with such a high concentration would normally be subject, a new manufacturing process was used. In this, drying to a low moisture level is avoided, and the granules in consequence are true, nonporous solids.

[British Information Services, Bulletin No. 1340]

Two More Fertilizer Projects

The Government of India has allotted two more fertilizer projects—Barauni (Bihar) and Namrup Expansion (Assam)—to F.C.I. Ltd., each of which is stated to have a capacity of 1,51,800 tonnes of nitrogen. An incidental advantage in the implementation of these two projects will be the utilization of the design and engineering already done for the Durgapur and Cochin projects.

The total estimated cost of the Barauni project is about Rs. 4,034.46 lakhs of which the foreign exchange cost will be of the order of Rs. 1,468 lakhs. Using petroleum naphtha as the main feedstock available from the nearby refinery, the factory when commissioned will produce 3,30,000 tonnes of urea every year.

The Namrup expansion project will be located near the FCI's Namrup project. The Expansion project will also produce 3,30,000 tonnes of urea every year using an estimated 25 million cft. of natural gas from the Nahorkatiya—Moran region as basic raw material. The total estimated cost on the project will be Rs. 2,946.53 lakhs of which Rs. 1,239.49 will be the foreign exchange cost.

[FCI News, 5 (3) (1967), 2 and 9]

Seminar on Fertilizer

A 2-day national seminar on 'Productivity in Fertilizer Industry' was organized at FCI, Nangal on March 31 and April 1, which was inaugurated by Sri Dharma Vira, Governor of Punjab and Haryana. The seminar reviewed the impact and application of latest management techniques in the setting up and efficient operation of fertilizer plants. The main subjects at the discussions were: (1) PERT/CPM as applied to the construction and expansion of fertilizer plant; (2) preventive maintenance in the fertilizer industry; (3) work study in the fertilizer industry and (4) fuller utilization of plant facilities.

[FCI News, 5(3) (1967), 34]

STATISTICS

TABLE 1—COMPARATIVE ECONOMICS OF NITROPHOSPHATES, AMMONIUM PHOSPHATE NITRATE, AND UREA-AMMONIUM PHOSPHATE PROCESSES^a

	A Nitrophosphate Odda Calcium Removal (20-20-0)		B Nitrophosphate HNO ₃ H ₃ PO ₄ (20-20-0)		C Ammonium Phosphate Nitrate (26-26-0)		D Urea-Ammonium Phosphate (29-29-0)	
	\$/s. ton product	\$/unit plant food	\$/s. ton product	\$/unit plant food	\$/s. ton product	\$/unit plant food	\$/s. ton product	\$/unit plant food
Raw materials ^b								
Ammonia (\$ 32/s. ton) ^c	7.49	0.187	6.94	0.174	10.40	0.200	18.89	0.326
Nitric acid (60%) (\$11/s. ton) ^c	13.84	0.346	13.04	0.326	13.48	0.259	—	—
Phosphoric acid (54% P ₂ O ₅) (58/s. tons) ^{c,d}	—	—	14.78	0.370	28.23	0.543	30.44 ^e	0.525 ^e
Phosphate rock (33% P ₂ O ₅) (\$13/s. ton)	8.80	0.220	3.07	0.077	—	—	—	—
Conditioner (\$ 50/s. ton)	1.01	0.025	1.01	0.025	1.01	0.019	1.01	0.017
Loss (1% of production cost)	0.42	0.011	0.46	0.012	0.62	0.012	0.64	0.011
Subtotal	31.56	0.789	39.30	0.984	53.74	1.033	50.98	0.879
Operating cost ^b	10.25	0.256	9.47	0.236	11.41	0.219	16.31	0.281
Total production cost	41.81	1.045	48.77	1.220	65.15	1.252	67.29	1.160
Return (20% pretax)	6.83	0.171	6.36	0.159	7.60	0.146	10.10	0.174
Nitrogen solution credit (\$1.28/unit)	-15.36	-0.384	-15.36	-0.384	-19.97	-0.384	-22.27	-0.384
Sales expense	8.39	0.222	8.89	0.222	10.48	0.201	11.10	0.191
Wholesale price f.o.b. bulk \$/s. ton product	42.17	—	48.66	—	63.26	—	66.22	—
\$/unit plant food	—	1.054	—	1.217	—	1.215	—	1.141

^a 250 short tons/day each of N and P₂O₅ as 1 : 1 : 0 and 150 short tons/day of N as solution, Investment costs, exclusive of plants for ammonia, nitric acid, sulphuric acid phosphoric acid but including nitrogen solution plants and working capital:

A, \$14 million; B, \$13 million; C, \$12 million and D, \$14 million.

^b Includes production of nitrogen solution.

^c Captive-use costs, including profit.

^d Based on sulphur at \$26/short ton, delivered.

^e 40% P₂O₅ acid at \$42/short ton.

[Phosphorus & Potassium, No. 26 December 1966, p. 22]

TABLE 2—POOL ISSUE & RETAIL PRICES OF SOME FERTILIZERS, Rs./m. tonne

[Revised by Union Ministry of Food & Agriculture w.e.f. 1.4.1967]

	States	Plantations	Retail price for plantation and cultivators*
	Rs.	Rs.	Rs.
Ammonium Sulphate (100 kg)	437/-	462/-	492/-
Ammonium Sulphate (50 kg)	448/-	473/-	503/-
Urea	760/-	800/-	840/-
Ammonium Sulphate Nitrate	515/-	544/-	577/-
Calcium Ammonium Nitrate (20.5%)	385/-	406/-	437/-
Imported Calcium Ammonium Nitrate (26%)	475/-	—	535/-
Diammonium Phosphate	1,000/-	1,050/-	1,095/-
Imported Ammonium Phosphate	738/-	—	818/-
Imported Ammonium Chloride	450/-	—	505/-
Imported Basic Slag	260/-	—	304/-
Imported NPK Complex	700/-	—	775/-

*In the States of Kerala, Madras, Mysore, Assam & West Bengal

[Letter No. FAI/Sec/14.2/3934/67 of April 6, 1967]

TABLE 3—INDUSTRY WISE REQUIREMENTS OF SULPHURIC ACID, 1965-66

Industry	Estimated requirements of sulphuric acid in 1965-66 ('000 tonnes)	%
Superphosphate and ammonium phosphate	904	59.3
Ammonium sulphate and nitro-phosphate	203	13.3
Rayon yarn and staple fibre	137	9.0
Aluminium sulphate	41	2.7
Pickling of finished steel	31	2.0
Titanium dioxide	24	1.6
Petroleum refining	16	1.1
Miscellaneous (including salts, acids, industrial explosives, dyestuffs, drugs, etc.)	168	11.0
Total	1,524	100.0

[Mines & Minerals, Vol. 3 No. 4, p.4]

TABLE 4—PRODUCTION OF SULPHURIC ACID, CONSUMPTION AND IMPORTS OF SULPHUR INTO INDIA, 1960-65

Year	Production of sulphuric acid in tonnes	Estimated consumption of sulphur for sulphuric acid alone in tonnes	Imports		Extent of consumption of sulphur in the total imports (in %)
			Quantity (Tonnes)	Value (Rs. '000)	
1960	353,940	127,418	178,904	27,347	71.2
1961	422,496	152,099	191,433	30,242	79.5
1962	469,464	169,000	248,031	47,410	68.1
1963	568,152	204,535	261,018	49,008	78.4
1964	678,636	244,309	341,161	45,228	101.6
1965	679,240	244,507	283,248	61,631	86.3

[Mines & Minerals, Vol. 3 No. 4, p. 5]

TABLE 5—SUPPLY POSITION OF SULPHUR DURING 1966

During 1966, contracts for 248,000 tons were finalized and a quantity of 213,676 tons was imported. Taking into account spillover from 1965, the position was as given

Source of supply	Contract	Procurement	Balance
(1)	(2) (1966)	(3)	(4) = (2) - (3)
1. U.S.A. (GSA) ¹	15,000	15,000	—
2. Poland ¹	10,000	10,000	—
3. Sulexco ¹	100,000	100,000	—
4. Texas Gulf ²	50,000	29,676	20,324
5. Free Port ²	42,000	42,000	—
6. Free Port (2nd contract) ²	21,000	7,000*	14,000
7. NDR Scheme	10,000	10,000	—
Total	248,000	213,676	34,324
8. Spillover from 1965 ³		26,257	—
Grand Total	248,000	239,933	34,324 ⁴

The total requirement for the year under review was 475,000 tons. Comparing it with the import position a gap of 235,067 tons was observed. Thus, procurement to the extent of 55 per cent was made which resulted in serious setback to the production of fertilizers.

Canalization of sulphur through the STC effected from August 27, 1966 was not observed to improve the procurement situation.

¹ Imported during 1st half year of 1966

² Imports effected during 2nd half year of 1966.

³ Against 35,000 tons of Canadian sulphur.

⁴ Expected during the 1st quarter of 1967.

* Estimate.

[FAI Inf. Serv., 8 (3) (1967), 5]

TABLE 6—PROCUREMENT OF ROCK PHOSPHATE DURING 1966, (tons)

Source of Supply (1)	Contract 1966 (2)	Procurement (3)	Balance (4)= (2)–(3)	Remarks
1. Morocco	200,000	201,404	—	Imports started from April 1966
2. Tunisia	300,000	237,077	62,923	Imports started from March 1966
3. Jordan	200,000	248,004	51,996	Imports started from April 1966
4. Egypt	150,000	101,069	48,931	Imports started from Feb. 1966
5. Togo	50,000	40,703	9,297	Imports started from May 1966
6. Algeria	70,000	10,300	59,700	Imports started from Dec. 1966
Total:	1,070,000	838,557	232,847	
7. Spillover from 1965	—	94,926	—	
Grand Total	1,070,000	933,483	232,847	
**Morocco	3,236 against 1964 contract)			
Tunisia	29,370			
Jordan	52,020			
Egypt	10,300			
	94,926			

Through barter.

Except Egypt, imports of rockphosphate from other sources started from March/April. Receipt of material from Algeria was effected as late as December. This situation resulted in the accumulation of large spillover of 232,847 tons from these contracts.

Enough sulphur was not available during 1966 to process adequate quantities of rockphosphate, with the result that its stocks mounted with fertilizer manufacturers.

Taking into account these stocks, spillover from 1966 (232,847 tons) and supplies expected during 1967, it is hoped that so far as the demand of rockphosphate is concerned, estimated at 1,400,000 tons, it is likely to be met in full.

Full utilization of this tonnage as also of fertilizer capacities is linked with adequate supply of sulphur during 1967.

[FAI Inf. Serv., 8 (3) (1967), 9]

TABLE 7—MAXIMUM PRICES OF SOME FERTILIZERS

Government of India under notification no. 16-3/66-M dated Jan. 28, 1967 has fixed the maximum prices per metric tonne of the following fertilizers (mentioned in schedule below) with effect from Feb. 1, 1967

Name of Fertilizer	When sold for the use of tea, coffee, or rubber plantations in the States of Kerala, Madras, Mysore, Assam and West Bengal	When sold for the use of cultivators
	Rs.	Rs.
1. Ammonium Sulphate		
(i) When packed in 100 Kg. bags	415.00	405.00
(ii) When packed in 50 Kg. bags	426.00	416.00
2. Ammonium Sulphate Nitrate	525.00	515.00
3. Urea	690.00	680.00
4. Calcium Ammonium Nitrate	395.00	385.00

Explanation:—The maximum prices specified above shall not include sales tax or other local taxes, wherever levied.

Note:—When sales of any fertilizer are made in quantities not exceeding 5 kilograms at a time, the dealer may charge 1 Paisa per kilogram, in addition to the proportionate maximum price specified above.

[FAI Inf. Serv., 8 (3) (1967), 4]

TABLE 8—RELATIVE POSITION OF PRICES OF WHEAT, RICE AND FERTILIZERS
(N, P₂O₅ & K₂O) IN DIFFERENT COUNTRIES (1964-65)

Country	Price per kg. in U.S. cents					Kg. of wheat required to buy one kg. of			Kg. of rice required to buy one kg. of		
	Wheat	Rice	N (S/A) 1964-65	P ₂ O ₅ (Sup) 1964-65	K ₂ O (MOP) 1964-65	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Australia	6.0	—	29.4	7.8	11.3	4.9	1.3	1.9	—	—	—
Belgium	9.8	—	27.0	16.9	—	2.8	1.7	—	—	—	—
Canada	6.4	—	34.7	25.0	11.9	5.4	3.9	1.9	—	—	—
France	10.3	—	25.5	12.6	7.0	2.5	1.2	0.7	—	—	—
Germany Fed. Rep.	10.7	—	26.2	20.8	7.2	2.6	1.9	0.7	—	—	—
Italy	10.9	10.7	25.6	17.1	10.9	2.3	1.6	1.0	2.4	1.6	1.0
Japan	12.5	27.6	26.4	24.4	9.7	2.1	2.0	0.8	0.9	0.9	0.4
Netherlands	9.5	—	28.3	21.5	9.2	3.0	2.3	1.0	—	—	—
Pakistan	9.9	15.0	17.4	12.6	6.0	1.8	1.3	0.6	1.2	0.8	0.4
Taiwan (China)	—	14.5	44.0	23.6	12.5	—	—	—	3.0	1.6	0.9
U.A.R.	6.1	4.4	31.1	17.1 ¹	8.9 ¹	5.1	2.8	1.5	7.1	3.9	2.0
U.K.	7.2	18.4*	16.3	13.3	11.3	2.3	1.8	1.6	0.9	0.7	0.6
U.S.A.	5.0	19.3	27.8	22.3	9.8	5.6	4.5	2.0	1.4	1.2	0.5
India	12.2	11.9	36.7	30.9	13.1 ²	3.0	2.5	1.1	3.1	2.6	1.1

* 1963 price.

¹ 1962-63 price,

² 1963-64 price.

SOURCE: FAO Yearbook 1965

[Fertilizer Statistics, 1965-66, (Fertilizer Association of India, New Delhi), Feb. 1967, 300-301]

TABLE 9—FERTILIZER PRICES PAID BY FARMERS 1964-65

(Rs. per metric tonne of nutrient)

Country	Ammonium Sulphate	Ammonium Nitrate	Calcium Nitrate	Urea	Single Superphosphate	Basic slag	Sulphate of potash	Muriate of potash
@ Austria	1,261	—	1,833	1,238	728	666	576	371 ¹
@ Belgium	1,285**	1,276	1,652**	1,138	804**	590**	514	390 ¹
* France	1,214	962	1,476	—	600	338	533	333 ¹
* Germany West	1,247	—	1,514	—	1,228	643	466	432 ²
* Italy	1,219	1,066	1,533	—	814	776	724	524 ³
* Netherlands	1,347	1,247	1,628	—	1,023	757	—	438
United Kingdom (at farm gate)	776	876	—	—	633	472	628	538 ¹
U.S.A.	1,323	1,233	—	—	1,061	—	—	466
Ceylon	1,195	—	—	843	643 ⁵	—	—	471
* China Taiwan	2,094	—	—	1,704	1,123	—	714	595
India	1,747	—	—	1,338	1,471	—	800	624
Japan	1,257	1,138	—	1,152	1,091	—	685	462
Korea Rep. of	1,299	1,399	—	1,066	833 ⁵	—	700	414
* Nepal	2,794	—	—	—	3,441	—	—	1,376
Pakistan	828	—	—	600	600	—	—	286
* Philippines	1,704	—	—	—	1,304	—	—	723
Thailand	1,328	—	1,933	1,147	990	—	585	428
* U.A.R.	1,490	—	1,761	—	—	—	547	424 ⁷
Australia	1,585	—	—	—	371	—	838	538
Morocco	1,852	1,171	2,479	1,656	557	1,099	914	628
* Jordan	1,652	—	—	—	1,185	—	—	652

@ Prices at nearest railway station

* No subsidies

¹ 60% K₂O, ² 50% K₂O, ³ 50-52% K₂O, ⁴ Over 45% K₂O, ⁵ 25% P₂O₅ or over, ⁶ 1962, ⁷ 1962-63

AUSTRIA: Subsidies on phosphate and potash paid to manufacturers and transport agencies. (Nitrogenous fertilizers are unsubsidised.)

1. Single superphosphate Rs. 173.74 per m. tonne
2. Basic slag Rs. 318.92 per m. tonne
3. Sulphate of potash Rs. 130.90 per m. tonne
4. Muriate of potash (60% K₂O) Rs. 58.07 per m. tonne

UNITED KINGDOM:

1. Ammonium Sulphate Rs. 442.68 per m. tonne
2. Ammonium nitrate Rs. 433.16 per m. tonne
3. Single superphosphate Rs. 352.24 per m. tonne
4. Basic slag Rs. 247.52 per m. tonne

U.S.A.: Prices paid by farmers at varying points of delivery. Under Agricultural conservation programme there is cost sharing arrangement with farmers for fertilizers as well as other requisites but this is not considered as subsidy.

CEYLON: Prices ex-departmental stores in district. Prices shown reflect a subsidy of 50% for each payment. Subsidy of 33½% is allowed to members of Cooperatives on purchase of fertilizer on credit.

CHINA TAIWAN: Prices at firmers' nearest railway station. No subsidy.

INDIA: No uniform subsidy is given throughout the country. In some States a subsidy of 25% of cost is granted on phosphatic fertilizers.

NEPAL: Prices at sales depot. No subsidy.

PAKISTAN: 53% subsidy has been deducted from the prices shown. No subsidy allowed to the Pakistan Tea Association, Pakistan Tobacco Co. and Sugar Estates.

THAILAND: Price c.i.f. Bangkok. No subsidies.

JORDAN: Prices at Retail Stores. Calendar Year. No. Subsidies.

AUSTRALIA: Prices are f.o.r. Yarraville. Subsidies paid to manufacturers. Subsidy on ammonium sulphate—Rs. 203.25 per tonne on single superphosphate—Rs. 142.80 per tonne.

MOROCCO: Prices at factory at Casablanca. Small-scale farmers receive a rebate of Rs. 471.24 per metric tonne of fertilizers. For demonstrations a rebate of 25% of the price is given on nitrogenous and complex fertilizers. Payment is made to farmers through cooperatives.

[Fertilizer Statistics 1965-66 (Fertilizer Assn. of India, New Delhi), Feb. 1967, 289-290]

TABLE 10—FERTILIZER CONSUMPTION PER HECTARE OF AGRICULTURAL LAND 1964-65

Continent/country	N	P ₂ O ₅	K ₂ O	Total
A. EUROPE	24.17	23.14	22.44	69.75
1. Austria	18.42	28.79	36.85	84.06
2. Belgium	97.31	77.38	106.58	281.27
3. Czechoslovakia*	25.93	32.53	40.28	98.74
4. Denmark	55.01	40.38	59.42	154.81
5. Finland	31.82	44.85	36.75	113.42
6. France	23.51	37.35	28.43	89.29
7. Germany East	47.82	40.89	84.34	173.05
8. Germany West	55.56	55.95	83.84	195.35
9. Italy	19.72	19.57	70.67	109.96
10. Netherlands	129.50	49.03	61.33	239.86
11. Norway	62.14	48.37	49.75	160.26
12. Poland	17.53	13.57	17.92	49.02
13. Spain	10.36	9.88	2.59	22.83
14. Sweden	38.94	31.60	26.98	97.52
15. United Kingdom	29.63	23.80	22.21	75.64
B. U.S.S.R.	2.93	2.14	2.37	7.44
C. NORTH & CENTRAL AMERICA	7.73	5.57	6.63	17.93
1. Canada**	2.38	3.81	1.74	7.93
2. U.S.A.	9.80	7.26	6.03	23.09
D. SOUTH AMERICA	0.80	0.85	0.57	2.22
1. Chile	2.86	5.55	1.04	9.45
2. Peru	3.53	1.64	0.45	5.62
E. ASIA	3.85	1.96	1.55	7.34
1. Ceylon	20.51	0.74	13.99	35.24
2. China Taiwan	153.52	41.10	39.53	234.15
3. India	2.88	0.84	0.35	4.07
F. AFRICA	0.50	0.27	0.21	0.98
1. South Africa*	0.82	0.87	0.60	2.39
2. U.A.R.*	—	—	—	—
G. OCEANIA	0.13	2.40	0.34	2.87
1. Australia	1.03	1.75	0.14	2.92
2. New Zealand	0.54	21.89	6.51	28.94
WORLD***	3.79	3.25	2.74	9.78

* Figures refer to the year 1962-63

** Figures refer to the year 1963-64

*** Excluding Mainland China.

Note: 1. Data on agricultural land have been taken from table 9.1 of Part II. Agricultural land includes arable land plus permanent meadows and pastures defined as land under herbaceous forage crops other than rotation grasses and clover.

2. Calculated on the basis of consumption figures furnished in Tables 1, 11.2 & 11.3.

[Fertilizer Statistics 1965-66 (Fertilizer Assn. of India, New Delhi) Feb. 1967, 289-290]

TABLE 11—REQUIREMENTS FOR UREA

Sl. No.	Characteristics	Fertilizer Grade		Urea
		Coated	Uncoated	
(i)	Moisture, per cent by weight, Max.	1.0	1.0	0.5
(ii)	Total nitrogen, per cent by weight (on dry basis), Min.	44.0	45.0	46.0
(iii)	Biruet, per cent by weight, Max.	1.5	1.5	1.5
(iv)	Free ammonia (as NH ₃), per cent by weight, Max.	—	—	0.01
(v)	Ash, percent by weight, Max	2.5	—	—
(vi)	Iron (as Fe), percent by weight, Max	—	—	0.0002
(vii)	pH of 10 per cent solution	—	—	7.0 to 9.5

Description: The material of the technical grade of both types shall be in the form of prills, granules or crystals and the material of the pure grade shall be in the form of white prills or crystals. The material of any grade shall be free from visible impurities and from dust.

Particle Size: In the form of granules, the material shall pass IS Sieve 320 (aperture size 3180 microns) and not less than 80 per cent by weight of it shall be retained on IS Sieve 100 (aperture size 1000 microns). If in the form of prills, the material shall pass IS Sieve 200 (aperture size 2032 microns) and not less than 80 per cent by weight of it shall be retained on IS Sieve 100.

Packing: The material shall be packed in jute bags lined with multiwalled paper or suitable plastic material or in such other containers as agreed to between the purchaser and the vendor. The weight of the material in a bag should ordinarily be 50 kg.

[Indian Standards Specification for Urea, Technical & Pure IS : 1781-1961 (Indian Std. Inst., New Delhi), June 1961]

TABLE 12—REQUIREMENTS FOR AMMONIUM SULPHATE, TECHNICAL

Sl. No.	Characteristics	Requirements
(i)	Moisture per cent by weight, Max.	1.0
(ii)	Ammoniacal nitrogen, per cent by weight, Min.	20.6
(iii)	Free acidity, (as H ₂ SO ₄), per cent by weight, Max.	0.025
(iv)	Arsenic (as As ₂ O ₃), per cent by weight, Max.	0.01
(v)	Pyridine (C ₅ H ₅ N), per cent by weight, Max.	0.01

Description: Ammonium Sulphate, Technical, shall be in the form of colourless crystals and free from visible impurities.

Packing: The material shall be packed in jute or multiwall paper bags or jute bags lined with polythene films or in such other containers as agreed between the purchaser and the vendor.

[Indian Standards Specification for Ammonium Sulphate, Technical IS : 826-1955, (Indian Stand. Inst., New Delhi), March 1956]

TABLE 13—REQUIREMENTS FOR AMMONIUM SULPHATE
NITRATE (Double Salt)

Sl. No.	Characteristics	Requirements
(i)	Total nitrogen (as N), per cent by weight, Min.	26.0
(ii)	Ammoniacal nitrogen (as N), per cent by weight, Min.	19.25
(iii)	Nitrate nitrogen (as N), per cent by weight, Max.	7.0
(iv)	Moisture, per cent by weight, Max.	1.0
(v)	Free acidity (as NHO_3), per cent by weight, Max.	0.015

Description: The material shall be free-flowing and shall be in a suitably coated form so as to retard caking and moisture absorption. It shall be of reasonably uniform shape approaching spherical.

Particle Size: The particle size of the material shall be such that the portion that passes through IS Sieve 400 (aperture 4000 microns) and is retained on IS Sieve 100 (aperture 1000 microns) is not less than 95 per cent by weight of the material taken for the test.

Packing: The material shall be packed in suitable moisture proof containers as agreed to between the purchaser and the supplier, and securely closed.

[Indian Standards Specification for Ammonium Sulphate Nitrate IS : 2256-1962 (Indian Std. Inst., New Delhi), Feb. 1963]

TABLE 14—REQUIREMENTS FOR SUPERPHOSPHATE

Sl. No.	Characteristics	Requirements	
		Grade I	Grade II
(i)	Moisture, per cent by weight, max.	12.0	12.0
(ii)	Free phosphoric acid (as P_2O_5), per cent by weight, max.	4.4	4.0
(iii)	Water-soluble phosphates (as P_2O_5), per cent by weight, min.	18.0	16.0
(iv)	Available phosphates (as P_2O_5), soluble in neutral ammonium citrate solution and water soluble phosphate (as P_2O_5), per cent by weight, min.	18.5	16.5

Description: There shall be two grades of the material, namely grades I and II. The material shall be free from excessive lumps and shall not form a hard cake on storage.

Source: IS : 294-1962 of the Indian Standards Institution.

[Fertilizer Statistics, 1965-66, (The Fertilizer Assn. of India, New Delhi), Feb. 1967]

TABLE 15—REQUIREMENTS FOR TRIPLE SUPERPHOSPHATE

Sl. No.	Characteristics	Requirements
(i)	Moisture, per cent by weight, max.	12.0
(ii)	Free phosphoric acid (as P_2O_5), per cent by weight, max.	3.0
(iii)	Water soluble phosphates (as P_2O_5), per cent by weight, min.	40.0

Description: The material shall be free from excessive lumps and shall not form hard cakes on storage.

With respect to triple superphosphate containing more than 40 per cent by weight of available phosphate, soluble in water, the manufacturer should be entitled to a pro rata premium for every unit (1 per cent of water-soluble phosphate over and above the minimum 40 per cent) prescribed.

Packing: The material shall be packed in jute bags or multiwall paper bags lined with polythene films or in such other containers as agreed to between the purchaser and the vendor.

[Indian Standards Specification for Triple Superphosphate, IS : 1013-1965 (Indian Std. Inst., New Delhi), March 1957]

TABLE 16—REQUIREMENTS FOR POTASSIUM CHLORIDE,
FERTILIZER GRADE

Sl. No.	Characteristics	Requirements
(i)	Potash content (as K_2O), per cent by weight, Min.	58.0
(ii)	Sodium (as NaCl), per cent by weight (on dry basis), Max.	3.0

Description: The material shall be crystalline, white or light grey or pinkish in colour and free from visible contamination with clay and grit.

Moisture: Unless otherwise agreed to between the purchaser and the supplier, the material shall contain moisture not more than 0.5 per cent by weight of the undried material.

Packing: The material shall be packed as agreed to between the purchaser and the supplier.

[Indian Standards Specification for Potassium Chloride (Muriate of Potash), Fertilizer Grade IS : 2779-1964, (Indian Std. Inst., New Delhi), Sept. 1964]

TABLE 17—REQUIREMENTS FOR DICALCIUM PHOSPHATE

Sl. No.	Characteristics	Requirements
(i)	Moisture, per cent by weight, max.	8.0
(ii)	Available phosphate (as P_2O_5) soluble in neutral ammonium citrate solution, per cent by weight, min.	34.0
(iii)	Chlorides (as Cl), per cent by weight, max.	1.0
(iv)	Fulorides (as F), per cent by weight, max.	0.5

Description: The material shall be in the form of fine powder, white in colour and free from grit and other extraneous impurities.

Packing: The material shall be packed in jute bags or multiwall paper bags lined with polythene films or in such other containers as agreed to between the purchaser and the vendor.

[Indian Standards Specification for Dicalcium Phosphate, IS : 1023-1956 (Indian Std. Inst., New Delhi), March 1967]

TABLE 18—REQUIREMENTS FOR CALCIUM AMMONIUM NITRATE

Sl. No.	Characteristics	Requirements
(i)	Total nitrogen (as N), per cent by weight, min.	20.5
(ii)	Ammoniacal nitrogen (as N), per cent by weight, min.	10.25
(iii)	Moisture, per cent by weight, max.	1.0
(iv)	Calcium nitrate, per cent by weight, max.	0.5

Description: The material shall be free flowing and shall be in a suitably coated form so as to retard moisture absorption. It shall be in reasonably uniform shape approaching spherical.

Particle size: The particle size of the material shall be such that the material is completely retained on 1—mm IS Sieve, and not less than 80 per cent by weight of it, shall pass through 4—mm IS Sieve.

SOURCE: Publication No. IS: 2409-1963 of the Indian Standards Institution, Delhi.

[Fertilizer Statistics 1965-66 (The Fertilizer Association of India, New Delhi), 1967, 255]

Geometry of Space Time Configuration in the Light of the Theory of Universal Spherical Wave of the Energy Field of the Universe and Atom

By

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The configuration of a regular tetrahedron possesses unique properties which may be applied to analyse or synthesise any equilibrium space-time configuration. The significance of Pythagoras theorem in the light of tetrahedral evolutionary concept has been analysed. It has been shown that the law is applicable to analyse quantitatively any static configuration except curved or spherical ones. For the analysis of curved or spherical configurations, space-time dimensional relationship associated with variability has to be taken into account. It has been shown that the constant π is not an absolute constant and is, in fact, a particular case of constancy of space-time relationship in a particular nature of configuration. Generation of equilibrium configuration due to action and reaction of space-time coordinates has been made for a few elementary configurations. It is shown that every equilibrium configuration must maintain some characteristic constancy in inter-dimensional relationships of space-time coordinates depending on the reference dimension chosen as unit magnitude in the "reference frame of configuration". The effect of change of reference positions of coordinates to positions in space on relative space-time dimensional relationship in the configuration has been explained in case of three-directional coordinates. An attempt has also been made to explain a mode of transformation of a geometrical configuration into curvilinear one.

In the light of proposed mechanism of generation of equilibrium configuration due to space-time coordinates, the problem of parity in wave mechanics and the phenomena of k-meson decay have been discussed. Dimensional relevance in parity concept as well as in Planck's constant had also been discussed. The analysis brings about the inadequacy of dimensional significance in both; parity concept as well as Planck's constant.

Geometry of Space Time Configuration in Space Energy Evolution Starting With Regular Tetrahedral Concept

There are two significant laws in physical science:

(1) The law relating to propagation of energy radiation from a point source conventionally known as black body radiation and the relationship known as Stephans Law.

(2) The other relationship relates to conversion of matter into energy conventionally guided by equation after Einstein as $M=E/c^2$ where c^2 dimensionally is L^2/T^2 and M as ET^2/L^2 .

The former law applies to the propagation of radiation in space. The relationship explains that when energy is emitted from a point source how the intensity of the radiation radially varies with respect to the position of the source. Stephans relationship demonstrates that the intensity of radiation varies inversely as the fourth power of the temperature. It has been shown in the works entitled "Energy Field of the Universe and Atom", Part II, Technol., Vol. II, No. 4, 1965, that the dimension temperature is function of L/T . What the present theory seeks is to bring to light that both the laws viz. that of Stephans and Einstein are

governed by the relationship of dimensional variability as function of L/T . In the Stephans law which is applicable to emitted radiation, the emitted energy intensity is proportional to the fourth power of the variability function L/T , whereas in the case of Einstein's equation which applies to matter-energy inter-conversion, it is governed by $(L/T)^2$ the square of the variability function L/T . In the present theory, emission of energy is associated with the creation of space since energy is space and intensity of space is intensity of energy. Creation of space due to energy and, therefore, emission of energy by radiation which are the same thing involves four directional probabilities. The expression of four directional probability has conventional significance of space time continuum. One of the important postulates of the present theory is that the emission of energy and the subsequent creation of space is tetrahedral. The point source of energy if occupies the centroid of the regular tetrahedron, the direction of emission must be towards the four corner positions representing four directions of evolution and associate with them some magnitudes of variability as L/T .

Matter energy inter-conversion in the present theory is a three directional probability phenomenon such

that matter occupying one corner position of regular tetrahedron the other three make spiralling orbit along the three directions from that position.

In the theory of "Energy Field of the Universe and Atom", the important relationships in the above cases have been attempted to be brought out from different approaches: (a) the fourth power relationship was first shown in the article "Variable velocity of Light and its Influence on Matter, Energy, Space, Gravitation in Universal Equilibrium", *Technology*, 1 (1964), 1, 53—page 19 where the gravitational constant was analysed by conventional dimensional analysis but incorporating energy E as the fundamental dimension. The gravitational constant has dimensional association of L^5/ET^4 . Treating the gravitational constant as an absolute constant and arbitrarily putting its value as unity, the dimensional equation was written as $E/L = (L/T)^4$. E/L is the conventional dimension of force and proportional to magnitude of space/time variability as L/T raised to the power four as $(L/T)^4$; (b) in Part II "Energy Field of the Universe and Atom", Chapter I, pages 18—20, while explaining the mechanism of creation of space adopting different probabilities of change of the four positions with respect to centre, relationship $E/L = (L/T)^4$ was derived assuming all the four positions emanating simultaneously occupying the four corner positions of a regular tetrahedron. The relationship $M/L = (L^2/T^2)$ was similarly derived if the variation of three positions only were taken into consideration in one direction; (c) again, on pages 181—184 in the same work, the relationships $E/L = L^4/T^4$ and $ET^2/L^2/L$ was realised from consideration of mechanism of evolution by adopting numerical presentations; (d) the derivation of the relationships in the evolutionary concept was again discussed in article "Introduction to Understanding of the Theory of Universal Spherical Wave of the Energy Field of the Universe and Atom". *Technology* Vol. III, No. 2, 1966.

Derivation of same relationship from different angles by adopting different approaches leave no doubt about the fundamental nature of energy emanation, which has been identified with space and that intensity of space itself is intensity of energy. The mechanism of energy emission in space should, therefore, follow the same mechanism of evolution of positions in space assuming configuration starting from position of point source. What is meant by this is that just as energy of highest intensity assuming a point of position when radiates, it creates progressively, positions in bigger magnitudes of space configuration such that the energy intensity of space positions diminishes radially. How the

energy wave emanates from point source assuming tetrahedral configuration has been already described in detail in the previous works. Since it can be argued: if energy is space and that if a law governing emission of energy radiation in space could be found then exactly the same kind of relationship should also hold to emanation of progressively increasing magnitudes of spatial configurations from a point of emanating position. An attempt has been made in this article to examine these aspects taking into consideration conventional geometrical configurations.

The evolution of geometrical concept of spatial configurations from simplest form of configuration towards more complicated configurations and development of their various inter-relationships etc. must have been in the consideration of the ancient scientists while trying to understand the evolution of space. Because, when science of configuration was first thought of, the idea about configuration did not start obviously from assuming very complicated structures. Thinking must have started from the most elementary, the simplest and most isotropic configurations which subsequently were further developed towards more and more complicated ones. Thus one can logically think that the first configuration which the first scientists started with in their consideration was the regular tetrahedral configuration, since no other configuration simpler than a tetrahedron exists in four directional space. Naturally, it is not unreasonable to expect that the first scientists started developing concept of configuration from its least magnitude towards increasing magnitudes of space and more complicated configurations. They tried various alternative modes and must have found relationships governing each mode. It must have been realised that occurrence of positions in space gives rise to concept of configuration.

In this treatment, the development of configuration of positions in space starts from regular tetrahedral concept and in order to make measurements employing unit of measure of distance between positions in space, the least magnitude of measurements with certain frame of reference in the most elementary configuration, namely, regular tetrahedron is ascribed. The distance from the centroid of the tetrahedron to the centre of any triangular face may be logically considered as the least magnitude of unit distance. In terms of this unit distance, all measurements of positions vis-a-vis among themselves and the centre of elementary configuration and also the measurements of all derived positions relative to any position of the tetrahedron could be deduced by knowing only one relationship.

This theory, is known as Pythagoras theorem. Whether Pythagoras was really the author of this theorem or not is not the intention of the author in his present work; but the fact is that this law was known in this country in remotest time and this relationship was applied to various branches of science namely astronomy, trigonometry etc. The tetrahedral evolutionary concept formed the basis in various science and philosophical dictum which were evolved from Sankhya in ancient India.

Geometrical Aspects of the Tetrahedron Configuration: Special Features of Configuration of Regular Tetrahedron

The static configuration of regular tetrahedron associates with it and provides a number of fundamental data in measuring the magnitudes of distance between positions in space in geometrical configurations which can form the basis of measurement of various dimensions in a static configuration. In the configuration of a regular tetrahedron, the least distance in the configuration is between the centre and the mid point of the triangular face. No other magnitude of distance between the centre and the various other conceivable positions in the evolved configuration of four positions including their distances between two positions would be less than the distance between the centre and the mid point of triangular faces.

In a regular tetrahedron, if the distance between the centre and the mid point of any one of the triangular faces would be taken as the unit of distance in space between two positions in the tetrahedral configuration, then the following relative magnitudes of dimensions in configuration as distance between two propositions, area between three and volume between four positions would be reckoned with as shown in figure 1a.

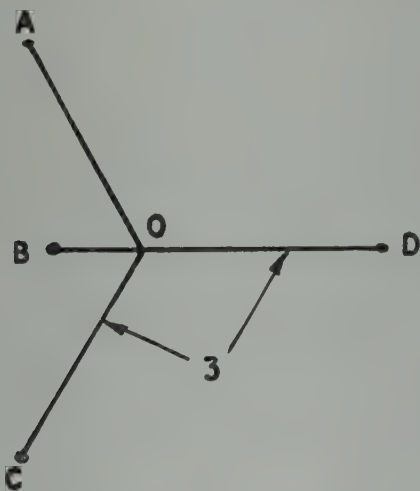


Fig. 1a—Showing radials emanating from centre O to the positions A, B, C & D.

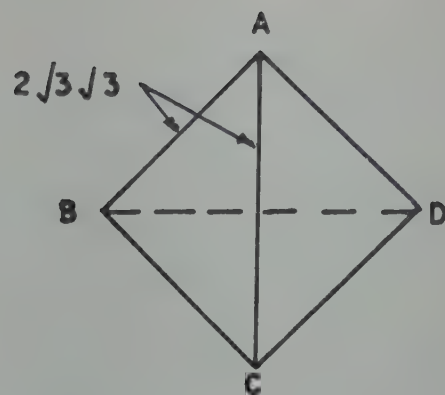


Fig. 1b—Seen normal to one side say AC.

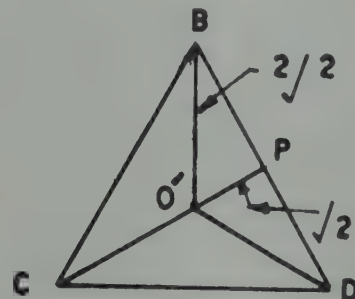


Fig. 1c—Showing one triangular face BCD, O' mid face, P mid side of BD, BC & CD.

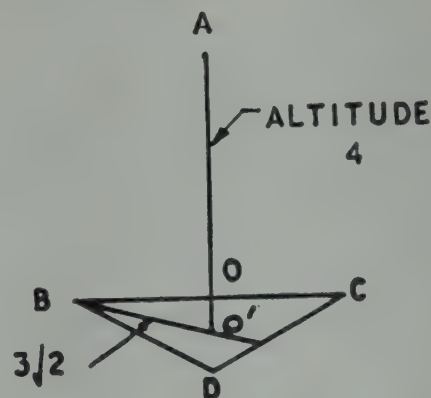


Fig. 1d—Altitude O'A 4 and Median of a triangular face $3\sqrt{2}$.

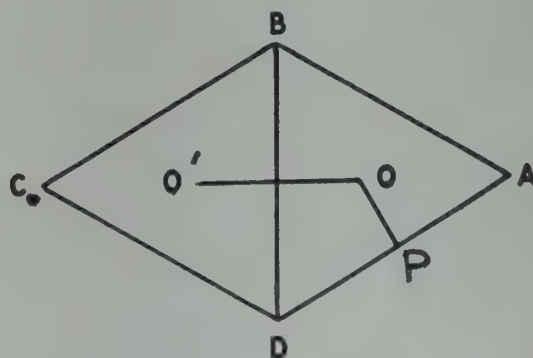


Fig. 1e—Centre to mid face OO' one unit of distance and centre to mid side $OP \sqrt{3}$.

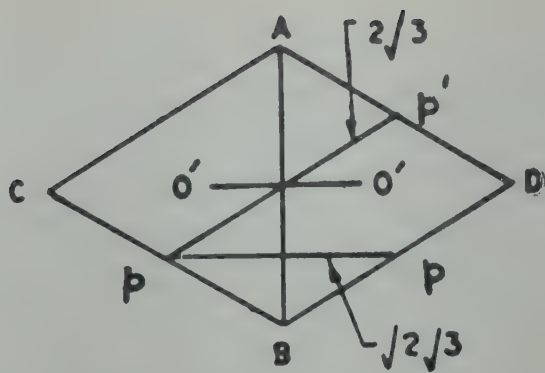


Fig. 1f—Distance between two mid sides: adjacent pp. $\sqrt{2} \sqrt{3}$ opposite pp. $2\sqrt{3}$.

1. Centre to mid face $OO' = 1(1e)$
2. Centre to mid side $OP \sqrt{3} (1e)$
3. Centre to corner $3(1e)$
4. Altitude $4(1d)$
5. Mid face to corner $O'B \ 2\sqrt{2} (1c)$
6. Mid face to mid side (nearest) $\sqrt{2} (1c)$
7. Mid face to mid side (distant) $\sqrt{2} \sqrt{3} = \text{half side} (1)$
8. median $3\sqrt{2} (1d)$
9. side $2\sqrt{2} \sqrt{3} (1b)$
10. area of one face $2.3\sqrt{3}$ 4 faces $8.3.\sqrt{3}$
11. volume of one quadrant $2\sqrt{3}$ 4 quadrants $8\sqrt{3}$
12. mid side to mid face (opposite) $2\sqrt{3}.\sqrt{4} \sqrt{3}$ (adjacent)
13. mid face to mid side $\sqrt{2} \sqrt{3}$ (4 such) and $2 \ 3$ (one such)

These are shown in the configuration of regular tetrahedron in figures 1a—1f.

In deducing these relationships, one geometrical law of measurement has been employed i.e. relationship between the sides in a right angled triangle (the theorem known as Pythagoras theorem).

Tetrahedron is the simplest of all configurations and also is the most perfect isotropic configuration in relation to both the centre and the corner positions as well as with respect to any position vis-a-vis the rest three positions. There is no comparable configuration which satisfies these two aspects equally. In the first aspect, when the four positions originally imagined to be condensed at the centre when emanate to give the configuration of the evolved tetrahedron, the emanation of the four positions involves four radial directions each one bearing equal angle $(109)^\circ$ with the other. In the second mode of evolution, the configuration would tend to be reduced from the four position originally condensed to one of the corner positions and from three positions will be evolved to make the tetrahedral configuration, the emanation of the three positions from one involves three directions. The difference between the two cases should be clearly understood. In the first case, the evolution is radial. The four positions in the evolved tetrahedron were

imagined to be condensed to one making the centre of the configuration. In the second case, at any of the evolved positions it may be imagined that the four positions were condensed to one where from three positions, with respect to the one fixed, emanate in three directions, making the tetrahedral configuration. In the first case, the evolution is four directional relative to the centre. In the second case, evolution of tetrahedron is three directional with respect to one fixed position. In the theory of universal spherical wave, these two aspects of development of configuration involving radial emanation of positions in four directional which have the similar significance of conventional four dimensional concept. In the evolved configuration, the variation of positions involves three directional variation or three dimensional probabilities. The regular tetrahedral configuration being the simplest configuration of positions in space. In this theory the radial directions are directions pertaining to space development and the orbital variations of three with respect to one of the evolved positions relate to time dimension in the energy space field configuration, all spatial configurations are made up of this simplest tetrahedral unit configuration and by proper analysis, all the configurations could be synthesised in terms of relative magnitudes that are obtained in unit tetrahedron.

In order to establish these points, we would illustrate this by a few comparably simpler and regular type of configurations namely, tetrahedron, octahedron, cube, and sphere. While making configurational analysis of these figures in terms of tetrahedron and the various relationships of its configuration, we would assume that in all these figures, all the positions describing the configuration are situated from the centre at equal units of distance. In the tetrahedron for example, units of distance from the centre to the corner positions are three and we shall consider in all the other configurations central distance to the positions having the same magnitude of distance. If the least unit of distance in a tetrahedron is between the centre and the mid point of a triangular face, then the distance from the centre to the corner positions is 3 units of distance. Similarly, the altitude of the tetrahedron is four units of distance. It will be seen in the subsequent deductions that with the help of these relative units of distance, in the tetrahedron measurement of all configurations can be suitably performed.

In Tables 1 and 2 various magnitudes of distance between various positions like side, altitude, median etc. in the configuration, the evolved surfaces, volumes

TABLE 1—MAGNITUDES ARE IN TERMS OF CENTRE TO MID FACE AS UNITS OF DISTANCE

Centre to Mid Triangular Face	Centre to Corner	Side	Median of Face	Altitude	Mid face to Mid Side	Mid face to Corner	Area of One Triangular Face	Volume of One Triangular Pyramid between Centre and One face	Surface to Volume Ratio
1	1.3	$1.2\sqrt{2}\sqrt{3}$	$1.3\sqrt{2}$	1.4	$1.\sqrt{2}$	$1.2\sqrt{2}$	$1^2.2.3\sqrt{3}$	$1^3.2.\sqrt{3}$	$(\sqrt{3})^2/1$
2	2.3	$2.2\sqrt{2}\sqrt{3}$	$2.3\sqrt{2}$	2.4	$2.\sqrt{2}$	$2.2\sqrt{2}$	$2^2.2.3\sqrt{3}$	$2^3.2.\sqrt{3}$	$(\sqrt{3})^2/2$
3	3.3	$3.2\sqrt{2}\sqrt{3}$	$3.3\sqrt{2}$	3.4	$3.\sqrt{2}$	$3.2\sqrt{2}$	$3^2.2.3\sqrt{3}$	$3^3.2.\sqrt{3}$	$(\sqrt{3})^2/3$
4	4.3	$4.2\sqrt{2}\sqrt{3}$	$4.3\sqrt{2}$	4.4	$4.\sqrt{2}$	$4.2\sqrt{2}$	$4^2.2.3\sqrt{3}$	$4^3.2.\sqrt{3}$	$(\sqrt{3})^2/4$

TABLE 2—MAGNITUDES ARE IN TERMS OF CENTRE TO CORNER POSITION AS UNITS OF DISTANCE

Centre to Mid Triangular Face	Centre to Corner	Side	Median of Face	Altitude	Mid face to Mid Side	Mid face to Corner	Area of One Triangular Face	Volume of One Triangular Pyramid between Centre and One face	Surface to Volume Ratio
1/3	1	$2\sqrt{2}\sqrt{3}$ 1/3	$1/3.3\sqrt{2}$	(1/3).4	$(1/3)\sqrt{2}$	(1/3) $2\sqrt{2}$	$(1/3)^2.2.3\sqrt{3}$	$(1/3)^3.2.\sqrt{3}$	$(\sqrt{3})^4/1$
2/3	2	$2\sqrt{2}\sqrt{3}$ 2/3	$2/3.3\sqrt{2}$	(2/3).4	$(2/3)\sqrt{2}$	(2/3) $2\sqrt{2}$	$(2/3)^2.2.3\sqrt{3}$	$(2/3)^3.2.\sqrt{3}$	$(\sqrt{3})^4/2$
3/3	3	$2\sqrt{2}\sqrt{3}$ 3/3	$3/3.3\sqrt{2}$	(3/3).4	$(3/3)\sqrt{2}$	(3/3) $2\sqrt{2}$	$(3/3)^2.2.3\sqrt{3}$	$(3/3)^3.2.\sqrt{3}$	$(\sqrt{3})^4/3$
4/3	4	$2\sqrt{2}\sqrt{3}$ 4/3	$4/3.3\sqrt{2}$	(4/3).4	$(4/3)\sqrt{2}$	(4/3) $2\sqrt{2}$	$(4/3)^2.2.3\sqrt{3}$	$(4/3)^3.2.\sqrt{3}$	$(\sqrt{3})^4/4$

of space generated by the positions of a regular tetrahedron of various increasing magnitudes of size has been shown. In table 1, the magnitudes of linear distances, surfaces and volumes have been calculated on the basis of distance between the centre and the mid triangular face as unit of distance. In table 2, the calculations have been based on the unit of distance as between the centre and the corner positions.

In tables 1 and 2, the magnitudes of dimensions relating to regular tetrahedral configuration, such as various distances like central distance to mid-face, central distance to corner position, evolved side, median of triangular faces, area of the evolved surfaces, volume enclosed by the tetrahedral configuration etc. have been considered. The relationships have been listed in order of increasing magnitude of size of tetrahedron. The central distance of mid face has been chosen as unit of distance in table 1; whereas in table 2, the

central distance to evolved corner positions has been taken as the unit of distance.

The following significant observations can be made from the two tables:

Table 1 and 2 show that the magnitudes of the evolved sides and medians are proportional to the central distance to mid faces in both the units of measurement (the evolved median of the triangular faces are proportional to the central distance to corner positions). Total areas of the triangular faces are proportional to squares of the central distances to mid triangular faces. Total volume enclosed by 4 plain triangular faces of the tetrahedron are proportional to the central distance to the mid triangular faces raised to the power 3.

The relationships for the evolved surfaces and volumes of the tetrahedron assuming distance (central) to mid triangular face as unit of distance would be $2.3\sqrt{3} R_1^2$

and $2/3 R_1^3$ where R_1 is the central distance to mid triangular faces (Table 1).

The corresponding surfaces and volumes (Table 2) of the tetrahedron if the units of distance would be taken from centre to corner positions then the area of the evolved surfaces of the tetrahedron would be

$$2.3\sqrt{3} \frac{R_2^2}{3^2} \text{ and the evolved volumes would be } 2.\sqrt{3} \frac{R_2^3}{3^3}$$

where R_2 is central distance to evolved positions.

The ratio of the evolved surface and the corresponding volume of the tetrahedron would be in the former case, $(\sqrt{3})^2/R_1$ and, in the latter case, the surface to volume ratio is $(\sqrt{3})^4/R_2$.

These two relationships must have significant bearing on the nature of evolution of space maintaining tetrahedral configuration. The surface to volume ratio is $(\sqrt{3})^2$ with respect to central distance R_1 to mid face as unit and the corresponding surface volume ratio with respect to unit distance from centre to evolved positions is $(\sqrt{3})^4$. These two different relationships have resulted from expression of the 2 cases in terms of two different units. In one case in which the unit distance has been reckoned from centre to mid point of evolved triangular faces and in the other case the unit distance has been reckoned from centre to the evolved corner positions. There has been no other conceivable factors that could have caused these differences in relationships in the two cases. When the unit distance is taken as from the centre to the mid face the surface volume ratio is some constant, i.e. $(\sqrt{3})$ raised to the power 2 and in the other case the surface volume ratio is proportional to the constant $(\sqrt{3})$ raised to the power 4. The first case is, in which the evolution of the tetrahedral space is considered up to the mid triangular face and in the second case the space evolution is up to the evolved corner position of the tetrahedron. In the first case the mid point of the triangular face has 3 degrees of freedom towards 3 evolved positions whereas in the second case the corner positions have reached the limit as far as the tetrahedral configuration is concerned and have also 3 degrees of freedom.

A significant conclusion from the above deductions can be drawn. In the first case, the evolution of space retaining tetrahedral configuration from least magnitude of space starting with 4 directional evolution to a position of 3 directional surface space having three

directional probability to positions is directly proportional to 3, which is a constant, $\sqrt{3}$ raised to the power two and inversely as central distance to mid face. In the second case, the tetrahedral evolution of space from 4 directional position to a state of position having three directional probabilities is directly proportional to the constant $\sqrt{3}$ raised to the power four and inversely as the central distance to the state of corner position. Surface to volume ratios in Tables 1 and 2 have been calculated in one direction.

Configuration of a Cube

It has been shown elsewhere in the various works on "Energy Field of the Universe and Atom" that the cube is a resultant configuration of two pairs of four positions having tetrahedral configuration each simultaneously appearing in opposite phases relative to the centre. It has been shown in previous works that when a tetrahedron vibrates between two opposite phases, i.e. the four positions making the tetrahedron in the first state would orient to the second state in which the other four positions are diametrically opposite to the previous state. Cube is thus an equilibrium configuration of four tetrahedral positions vibrating between opposite phases [refer Fig. 2(a)]. As a corollary, if somehow the four positions in any one phase could be masked from the observation, the appearance of the configuration would be tetrahedron corresponding

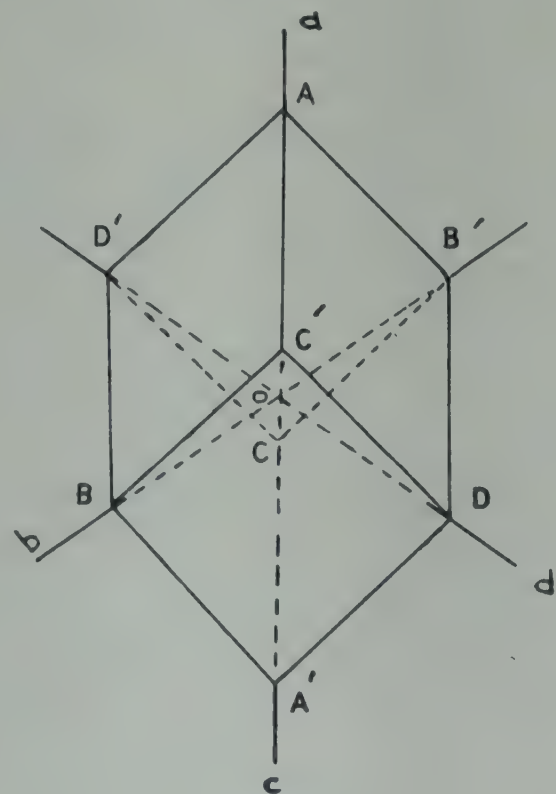


Fig. 2(a)

to one of the phases. In the equilibrium configuration of cube, the distance between two adjacent positions belonging to one tetrahedron of any one phase becomes the diagonal of the square surface of the cube whereas the distance between any two adjacent positions, one each from the tetrahedrons in the two phases becomes the edge or the side of the cube. The former retains the tetrahedral angle with the centre at 109° and the latter makes an angle of 71° with the centre of the cube.

This has been shown figuratively in figure 2a in which a, b, c and d are four positions in regular tetrahedral directions with respect to centre O. Along these main tetrahedral directions, the generation of the configuration due to the oscillation of the tetrahedral positions between two opposite phases generates the cubical configurations A,B,C,D A', B', C', and D'. The tetrahedral positions A, B, C, D belong to the first phase and A', B', C', D' belong to the opposite phase. There are 8 directions from the centre connected to 8 positions which is the sum of 4 positions of the first phase and 4 positions in the opposite phase. At the centre, these tetrahedral directions meet making either 109° , if they belong to same phase and 71° if they belong to opposite phases. In figure 2(b), one tetrahedron in one phase is shown and the cubical configuration with diagonals on the generated faces of cube with respect to one position say A, has been shown in figure 2(c). In figure 2d, the projected figure of the generated cube when seen through A', towards A, two opposite positions, has been shown. The significance of this is that in the right-angled isocelles triangle, say ABC', on one square face, say ACD'B' of the cube, in which the diagonal AC is the hypotenuse and the other two sides are AB' and B'C.

The 8 generated positions assuming the configuration of a cube retain the same magnitude of radial distances to corner positions as before from the centre. In the cube, the number of edges have become 12 as against original six of one tetrahedron. The magnitudes of the new edge of the cube and the original edge of tetrahedron (which have now become diagonal of the square face of the cube) are $2\sqrt{3}$ and $2\sqrt{2}\sqrt{3}$ respectively. It would be remembered that the least unit of distance in measurement in this case is the perpendicular distance between the centre and the mid point of triangular faces of the tetrahedron has been employed as unit.

It is significant to note that each diagonal on each of the square faces of the cube have two opposite positions on either side which exactly divides the face into

two isocelles triangular halves; the diagonal of positions say AC in figure 2(c) was the edge of the tetrahedron, makes right angle with the two opposite positions B' and D'. All the diagonals of the square faces also make isocelles triangles with the centre O in which each of the sides, which are radials, is equal in magnitude to 3 units of distance. The diagonals make isocelles triangle with the radials making an angle of 109° with the centre (because of regular tetrahedral configuration).

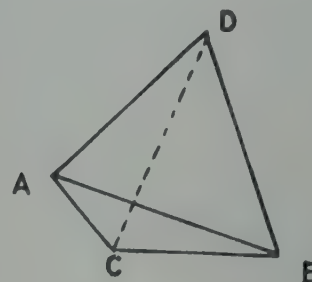


Fig. 2(b)

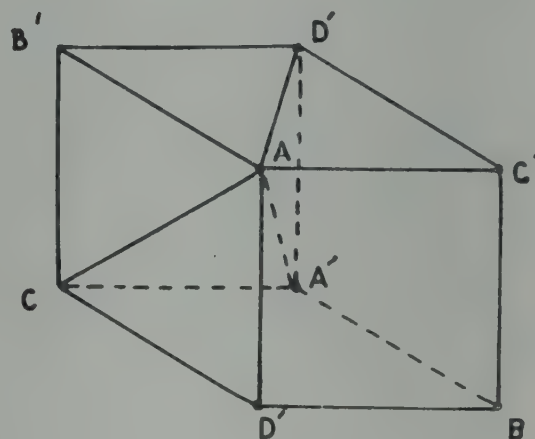


Fig. 2(c)

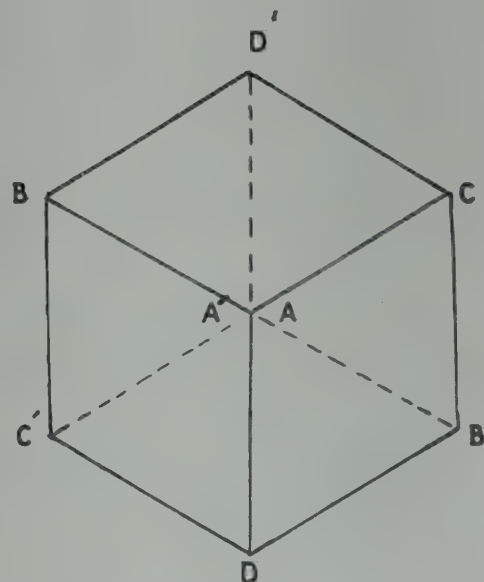


Fig. 2(d)

In the evolved square surface of the cube diagonals on each square surface make isocelles triangles on either side with the opposite positions but they make right angles.

In the following, it has been shown how the square of the diagonal of a square face is equal to two square faces of the cube. Each square surface is twice the area of one right angled isocelles triangle as shown in fig. 2e.

It should be remembered that the diagonal on the squared surface which is the hypotenuse of the right angled isocelles triangle is in reality one side of the configuration of tetrahedron from which the cube has been generated, having 12 equal sides viz. AC' , BC' and so on. This point that cube is the resultant equilibrium configuration generated out of two tetrahedrons vibrating between opposite phases and generates the configuration of cube which is less isotropic than the regular tetrahedron is significant. The 8 generated positions with respect to the centre retains isotropic characteristics but the evolved position with respect to one another do not retain such characteristics.

The elementary discussions in the above on the configurational aspects of the tetrahedron and cube have a definite purpose in the present context. The configuration of the regular tetrahedron gives a very significant radial distance between the centre and the evolved positions on the one hand and the centre and the mid point of the triangular surface on the other.

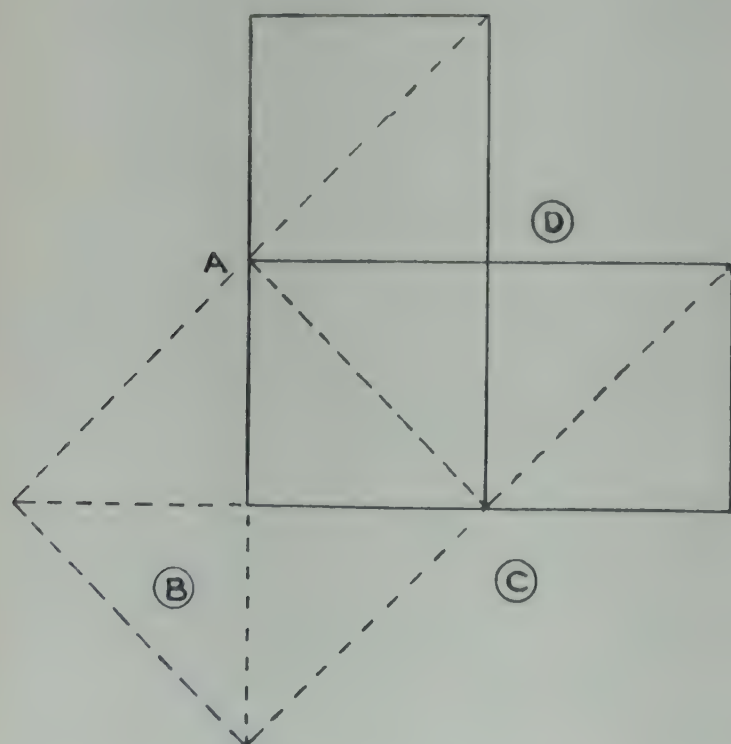


Fig. 2(e)

The tetrahedral configuration as such, however, does not provide direct data for the measurement of the distance between the positions on the surface of the evolved tetrahedron. The desired data could however be found from equilibrium configuration when the tetrahedral positions oscillating between the opposite phases describe the configuration of a cube. The square surfaces of the cube retain the edge of the tetrahedron as diagonal of the square faces. The diagonal is the hypotenuse of the right angled isocelles triangle of the square face of the cubes. A relationship between the hypotenuse and the sides of the new configuration of the cube can be easily found by simple diagrammatic presentation as in figure 2(e). It may be seen from the figure that when 3 square faces of the generated cube are projected as in the figure 2(e), sum of the two squares (obviously on the sides of the cube) are equal to the square on the hypotenuse, i.e. the square on the edge of the original tetrahedron from which the cube has been synthesised.

The first relationship that would be found could be stated as: The square on an edge of regular tetrahedron is equal to twice the squares on a side of generated cube having constant central distance to corner positions. The relationship thus obtained from the regular tetrahedron and the generated cube, however, apparently seems to be of limited value, because this relationship restricts itself in application to a right angled isocelles triangle. It has to be found out whether similar unique relationship also is applicable to any right angled triangle or not. Most important factor is to identify the right angled triangle in the configuration. After identification of the right angle in a configuration and the triangle, in order to find the relationship between the sides and the hypotenuse which would be applicable to any right angled triangle, it is important to establish one relationship between the hypotenuse and the two other varying magnitudes of sides of the triangle. In figures 2(f) and 2(g) and 2(h) an attempt has been made to find out this relationship on pro-

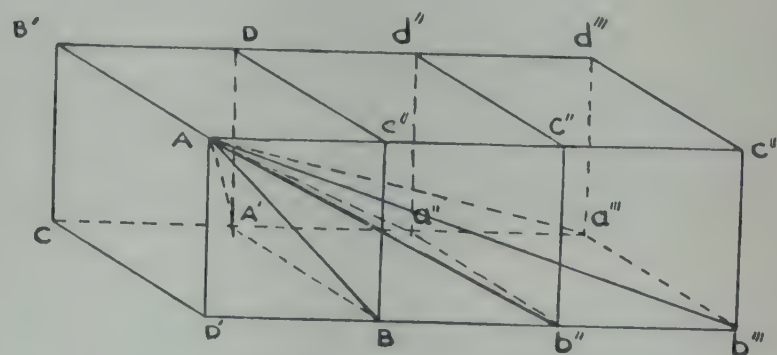


Fig. 2(f)

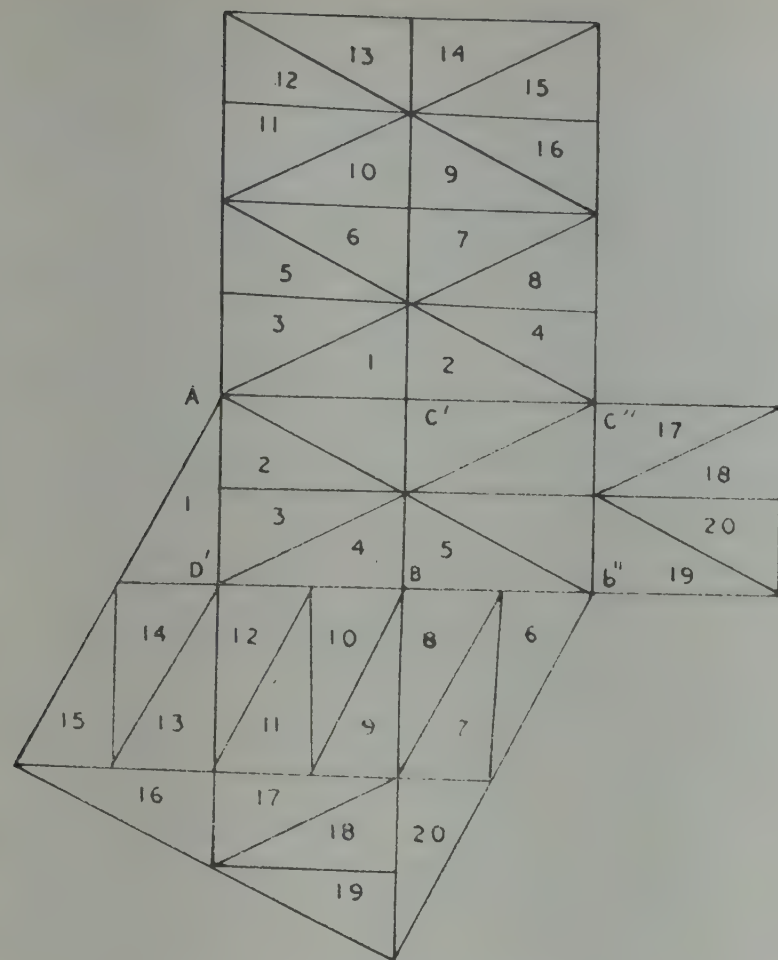


Fig. 2(g)

jected diagrams from elementary considerations. In figure 2(f), 3 unit cubes are placed in one direction one after another. The face of the cube is a regular square. When the two cubes are joined the sum of the two square faces of I and II is a rectangle $Ac''b''D'$. One of the sides is one unit and of the other 2 units of distance (side of cube is assumed as one unit). Half of this rectangular surface is the right angled triangle $Ac''b''$ of which Ab'' is the hypotenuse and Ac'' and $b''c''$ are the two sides whose relative magnitude of distance are 2 and 1 units respectively. The rectangular surface Ab'' has been projected in figure 2(g) and diagrammatically analysed as is shown in the figure. It may be seen that the sum total of the squares on the two sides is equal to 20 numbers of identical triangular unit surfaces. Similarly the analysis of the square on the hypotenuse also shows that this area equals to the sum total of 20 such units of triangular surfaces. In figure 2(h), 3 units of square surfaces [derived from fig. 2(f)] are added forming a rectangular surface having sides in the ratio of 3 : 1. Similar analysis as is done in fig. 2h would prove that in a right angled triangle the sum total of the squares on the 2 adjacent sides is equal to the square on the side opposite of these which is the

hypotenuse. This can be stated in another way: the hypotenuse is the root of sum of squares on two sides in a right-angled triangle.

This unique relationship between the 2 sides and the hypotenuse in any right angled triangle must have been found from these elementary considerations in the remote past. By knowing this relationship the various relative distances in the configuration of tetrahedron, cube, octahedron, icosahedron can be calculated in terms of magnitude of unit of distance from the centre of the parent tetrahedron to the mid point of the triangular faces.

Configuration of Octahedron

In the case of the cube we have shown that cube is an equilibrium configuration generated due to simultaneous occurrence or presence of 2 pairs of 4 regular tetrahedral positions in opposite phases. We shall now see that the configuration of octahedron is also an equilibrium configuration of positions from some component configuration vibrating between opposite

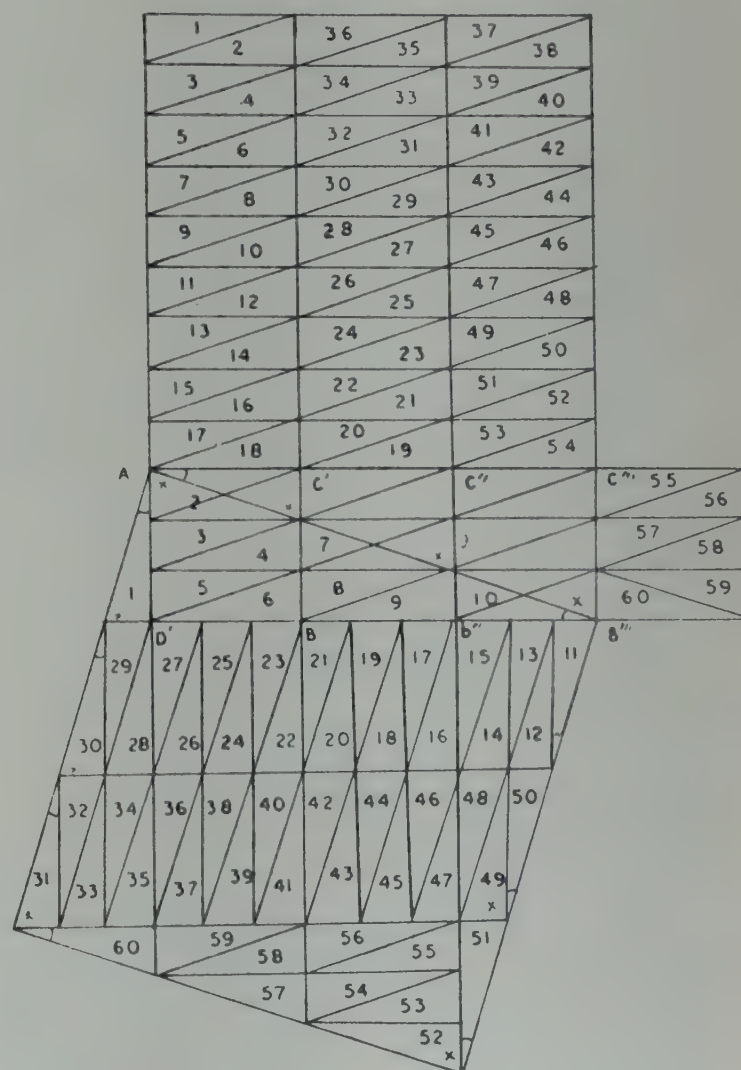


Fig. 2(h)

phases. In terms of the same magnitude of unit of distance in tetrahedron, the corresponding magnitudes in a regular octahedron having radius as $2\sqrt{3}$ units of distance and the distance between the centre to any of the mid points of the triangular faces is 2. The distance between the centre and the mid point of any side is $3\sqrt{2}$. Median of any evolved triangular face is $3\sqrt{2}$. The distance between any two evolved positions i.e. side of the octahedron is $2\sqrt{2}\sqrt{3}$. From analysis of the configuration of regular octahedron it would be seen that the configuration of octahedron is generated when the 3 positions of a tetrahedron vibrate between the opposite phases with one altitude say aa' of the tetrahedron as axis such that the 2 pairs of 3 positions bcd and $b'c'd'$ in opposite phases maintain a constant distance from the mid point of the altitude (not at the centroid of original tetrahedron as was in the case of generation of cube). The difference between octahedron and cube is that in the latter case the tetrahedral positions vibrate between opposite phases with respect to the centroid of the tetrahedron so that all the 8 evolved positions appear in the configuration; in the case of octahedron only 6 positions appear in the configuration, two positions a and a' have been masked from observation because when the positions vibrate between opposite phases as bcd and $b'c'd'$ with respect to the mid position of the altitude of the tetrahedron as the central equilibrium position of the equilibrium octahedral configuration, the mid point of the triangular face bcd of tetrahedron in one phase coincides with one corner position a' of the tetrahedron belonging to other phase. Hence strictly speaking the triangular face of octahedron consists of actually 4 positions of which 3 are visible being corner positions and the mid position forms the mid point of the triangular surface itself which is not observed. The other significant point is that angles at the centre between adjacent radials are at right angles. Inter-convertibility to one another. When a unit regular tetrahedron of 4 positions oscillate between two opposite phases with respect to the centre the developed 8 positions describe a cube whose sides are 2—3 units of distance. If the tetrahedral positions vibrate between two opposite phases such that a triangular face of three positions in first phase accommodates at the mid point of its face and position of the second tetrahedron in the opposite phase, and similarly mid point of one triangular face of tetrahedron in the second phase accommodates one position of tetrahedron in the first phase, then the generated configuration is octahedron whose sides are $2\sqrt{2}\sqrt{3}$ and 6 radials at right angles to each other at

the centre at $2\sqrt{3}$.

If however triangular pyramid covered by triangular face of the octahedron with the centre of octahedral configuration, instead of vibrating in opposite phases namely bcd and $b'c'd'$ with respect to the centre O_1 which makes the configuration octahedron O_1 forming the centre of the configuration, would vibrate between opposite phases face to face so that the distance of the apex positions of the two phases are at a distance of 6 units then the configuration becomes cube having the same size, as was shown before one generated from 2 tetrahedrons of unit size between opposite phases. To a regular octahedron of 8 tetrahedrons would be added to 8 triangular phases the resultant configuration would also be a cube.

If, however, only 4 tetrahedrons having equal face as the octahedron would be added to only 4 triangular faces of the octahedron such that at each alternate face is fitted one tetrahedron then the resultant configuration would be tetrahedron.

Particular mention of these aspects of the three configurations—tetrahedrons, octahedron and cube and their inter-convertibility from one configuration to the other has been made because that would give a clue to the inter-relationship and inter-convertibility of various systems of coordinates.

Actually the configuration of regular tetrahedron itself contains in it the significance of the configurations of cube and octahedron. For example the six mid points of sides of tetrahedron gives the configuration octahedron of 6 positions; these six positions also can be mid points of six faces of a cube.

In the tetrahedron with respect to the centre the 4 evolved positions are identical. In octahedron with respect to the diagonal made of two opposite positions as axis—the rest 4 positions are identical. In the configuration of the cube, with respect to the axis of two opposite positions two identical pairs of 3 positions in opposite phases are at equilibrium.

Significance of this (co-ordinates) on space time relationship in the three configurations will be discussed in a later chapter.

For example there are 4 identical quadrants, each one being triangular pyramid in the configuration of tetrahedron. There are 8 isosceles triangular right angled pyramids in 4 opposing directions in octahedron.

In the configuration of cube two right angled triangular pyramidal quadrants acting in opposition face to face generates the cube. The coordinates in octahedron and cube are both rectangular but are opposites in direction.

The universal configuration of spherical wave consisting of 5 tetrahedrons is a configuration in which each tetrahedral quadrant in the central tetrahedron act in opposition to another tetrahedral quadrant from opposite direction giving the resultant configuration of universal spherical wave.

Significant Relationships of Surface to Volume Ratio of Configurations

In Table 3 have been listed the various magnitudes of spatial dimensions between positions in configuration such as linear distances, altitudes, medians, surfaces and volumes of a few elementary configurations, viz. tetrahedron, octahedron, cube and sphere. In this table the distance between the centre and the evolved positions has been taken as 3 units of distance and is constant for all the configurations. Obviously since the unit tetrahedron has been chosen as one whose central distance to mid triangular face is one unit of distance and the distance between the centre and any corner position as 3 units of distance. The latter radial distance to the positions from centre remains constant for all the configurations. The progressive development of configurations starting with regular tetrahedron towards the generation of spherical surface having the same radius would take place through various configurations from tetrahedron through octahedron and cube etc. to sphere with increasing number of evolved positions generating the configurations. In the various configurations as the number of positions will increase describing the contour and surfaces for the configurations, the inter-distances between 2 adjacent positions will progressively become less as the number of positions increase. The area enclosed between any 3 adjacent

evolved positions also will correspondingly decrease till the surface would be spherical i.e. when the surface would consist of positions only and no free linear space in between any two adjacent positions or free surface area in between any three adjacent positions will remain. This is an extremely important aspect of configurations because the configurations other than the sphere will not have as many positions to generate the uniform curved surface and curvilinear lines between adjacent positions. There would be in between the positions linear distance, and plain surface etc. Therefore, in these tables, the data which have been based on the relationship of the right angled triangle will only hold good for configurations other than sphere and will not hold good for spherical configuration of positions because spherical surface is a configuration made of only positions having no space in between the adjacent positions. The theorem of Pythagoras is only applicable to geometry of plane surface in between positions in space and not to distances or surfaces described by continuity of the positions themselves with no space intervening. In other words, Pythagoras theorem is applicable to only measurement in configuration of positions in space and by proper application it can be made applicable to any configuration of positions in space of varying magnitude of units of spatial configurations.

The basic postulates in this theory is that the action of space is radial and action of time is orbital. In the theory of spherical wave energy creates space emanating in radial direction assuming tetrahedral configuration of evolution. The dimension matter assumes position in space and matter position describes time in configuration as orbits. Time measures the units of dis-

TABLE 3

Configuration	Centre to Mid face	Centre to Mid side	Centre to Corner	Median of Triangular face	Evolved Side	Total area of Faces	Total volume of Configu- ration	Surface to volume ratio
Tetrahedron	$(1/3).3$	$(1/\sqrt{3}).3$	1.3	$\sqrt{2}.3$	$\frac{2\sqrt{2}}{\sqrt{3}}.3$	$(8/\sqrt{3}).3^3$	$8/(\sqrt{3})^5.3^3$	$(\sqrt{3})^4 \ 1/3$
Octahedron	$(1/\sqrt{3}).3$	$(1/\sqrt{2}).3$	1.3	$(\sqrt{3}/2).3$	$\sqrt{2}.3$	$\left(\frac{8\sqrt{3}}{2}\right).3^3$	$\frac{8}{2(\sqrt{3})^3}.3^3$	$(\sqrt{3})^3 \ 1/3$
Cube	$(1/\sqrt{3}).3$	$(\sqrt{2}/\sqrt{3}).3$	1.3	$\left(\frac{\sqrt{2}}{\sqrt{3}}\right).3$	$\left(\frac{\sqrt{2}}{\sqrt{3}}\right).3$	8.3^3	$8/(\sqrt{3})^3$	$(\sqrt{3})^3 \ 1/3$
Sphere	1.3	1.3	1.3	Least	Least	$4\pi.3^3$	$4/3\pi 3^3$	$(\sqrt{3})^3 \ 1/3$

tance in the spherical curved surface which are described by matter positions themselves arranged in curvilinear orbits of positions of matter having no space in between adjacent positions. This fundamental difference between the two aspects of measurement of magnitudes of dimensions between positions in space in the 2 kinds of configurations spherical or curved and the rest, must therefore, be reckoned with. The measurement along the spherical surface which are in terms of T time dimension must also be measured in terms of dimension of T and not in terms of dimension of space by applying the relationships from a right angled triangle.

In matter/energy, space/time relationship in configuration, we have already shown that there are two kinds of relationships (which have been propounded in the theory of the spherical wave of the energy field of the universe and atom). The first relationship is $E/M=c^2$ which is Einstein's equation and dimensionally this can be expressed as

$$\frac{E}{ET^2/L^2} = L^2/T^2$$

The other dimensional relationship is $E/L=(L/T)^4$ which has been derived from the conventional gravitational equation is also similar in significance to Stephans Law of radiation, which in turn is based on Planck's law. Unlike the second relationship, E in the first relationship is not defined in relation to dimension space as L. In other words, E is not involved in the relationship as intensity as E/L and it is not possible to know the energy potential state.

The significance of constants $(\sqrt{3})^2$ and $(\sqrt{3})^4$ must have spatial significance in space time configuration (as was shown in tables 1 and 2) and must be having the dimensional significance as T/L.

It should be realised that space is energy and the intensity of energy varies inversely as the magnitude of size of space-configuration. Therefore, if the dimension energy as E is not associated with L, intensity of energy cannot be known. When matter is converted into energy as per equation $E=Mc^2$, after conversion unless the state of energy is also qualified, the relationship is not complete. If matter by association with the dimension L^2/T^2 would be converted into energy E, the varying magnitudes of L^2/T^2 must also have different influence on the converted energy state which can be only determined by knowing the intensity by associating E with L. Needless to say, in these respects the above equation $E/M=L^2/T^2$ is incomplete. Since space is radial and time is orbital, energy and matter intensity in space

would be E/L radial and M/T orbital.

This analysis would also be borne out by tables 1 and 2. Surface to volume ratio on tetrahedral evolution of space and the constants in the 2 cases are $(\sqrt{3})^2$ and $(\sqrt{3})^4$ in the tables are associated with the radial space distance from the centre to the mid triangular face in the one case and centre to the evolved positions in the other.

In the configuration of regular tetrahedron as such it is not difficult to see that there are two distinct entities in the configuration as surface between positions on the one hand and the evolved volumes between positions on the other. The theory of spherical wave of energy field differentiates further between positions themselves in space. In the homogeneous zone of the spherical wave, positions and space in the configuration form one. They are in one configuration, and the positions in this zone of the spherical wave are not distinct from space in the configuration in the sense that they cannot be separated, whereas the positions in the heterogeneous zone of the spherical wave are distinct from the space field surrounding it. The positions in the latter case pertain to elementary matter or mass and surrounding space is energy field with which the matter is in equilibrium.

Table 3 would throw further light on the subject. In table 3 elementary configurations viz. tetrahedron, octahedron, cube, sphere, are considered. In all these configurations the radial distances from the centre to

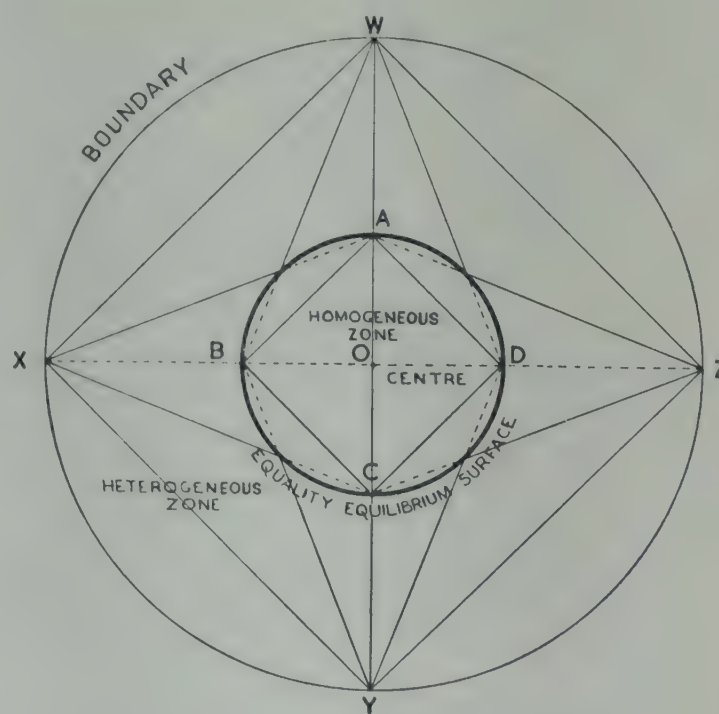


Fig. 3(a)

the evolved positions have been retained constant. Under these specified conditions, the tetrahedron and the sphere would relate to two extreme states of configuration. Tetrahedron has only 4 evolved positions. All other configurations including octahedron, cube, icosahedron etc. would have increased numbers of positions at constant radial distances from the centre in the evolved configurations. The configuration of sphere is one in which on the surface of the sphere at any instant any position would be found to be present, maintaining constant radial distance from centre. This should be the definition of sphere. While this would be the case, in the configuration of regular tetrahedron the distance between the evolved positions as well as the area of plane surface covered by any three positions would be maximum. As the number of positions of the configuration increases the distance between any two adjacent evolved positions would decrease; correspondingly the area of triangular faces between three adjacent positions would also decrease. The median of the triangular faces also would decrease in magnitude of distance. The sum total area (integrated) of the evolved plane surface would, however, tend to increase from tetrahedral configuration towards sphere and so also the total volume covered would correspondingly increase till they would become maximum with the spherical configuration. It would be seen from a perusal of table 3, that these conclusions are justified. Thus the factor or coefficient for evolved side decreases from $2\sqrt{2}\sqrt{3}$ for tetrahedron to least for sphere; factor for median from $3\sqrt{2}$ for tetrahedron reduces to least for sphere. The coefficient for surface increases from $\frac{8}{(\sqrt{3})^5}$ for tetrahedron to 4π for sphere. Similarly, factor for volume increases from $8/(\sqrt{3})^5$ for tetrahedron to $4 \times \pi\sqrt{3}$ for sphere.

In these configurations again if we consider the radial distances from the centre to the corner positions and the centre to the mid-points of the evolved surfaces, then we should expect that as the number of positions in the configurations will increase the area of the plane surface bounded by any three adjacent positions would progressively decrease and the radial distance from the centre to the mid-point of the evolved surface would progressively increase. Similarly, as the number of positions in the configuration would increase the radial distance from the centre to the mid-point of the evolved sides between 2 adjacent positions would also progressively increase till spherical configuration is arrived at in which all conceivable positions would be at constant radial distance from the centre. Thus we find from

table 3 that the factor for central distance to mid-face for tetrahedron increases from $1/3$ to 1 for sphere. Similarly the factor for the central distance to mid-sides increases from $1\sqrt{3}$ for tetrahedron to 1 for sphere.

The surface to volume ratio of the various configurations are $(\sqrt{3})^4/3$ for tetrahedron, $(\sqrt{3})^3/3$ for octahedron, $(\sqrt{3})^3/3$ for cube and $(\sqrt{3})^2/3$ for sphere.

These results clearly indicate that under constant magnitude of space evolution in configurations:

(a) Tetrahedral evolution of space is governed by $(\sqrt{3})^4$.

(b) If the configuration of evolution of space is other than tetrahedron or sphere, it may be octahedron, cube or icosahedron and the evolution of space will be governed by $(\sqrt{3})^3$.

(c) In the case of sphere the law governing it is $(\sqrt{3})^2$. The generalised conclusion which can be drawn from this is that the space evolution depicting pure tetrahedral configuration would be governed by $(\sqrt{3})^4$ and the other extreme configuration the sphere is governed by $(\sqrt{3})^2$. For other intermediate configurations, these are in between these two limit cases and are governed by $(\sqrt{3})^3$.

These results also bring about the applicability of the laws of geometrical configuration. In all intermediate configurations from tetrahedron to the sphere. the numbers of evolved positions in the configurations do not completely envelop the spherical surface. Some vacant space in between positions is left. Whereas in the case of sphere the entire spherical surface is all composed of evolved positions. No vacant space in between adjacent positions is left.

Pythagoras' theorem is applicable to all configurations in which in between the adjacent evolved positions some space is left. Whether this is linear distance between any 2 positions or the plane surface between any three adjacent positions or the volume enclosed by all the evolved surfaces in the configuration can all be measured by the application of the Pythagoras' theorem. But, for the measurement of volume and space relating to the configuration of sphere the factor π is brought in, which is not determined from this theorem. Pythagoras' theorem applies to configurations in which measurement takes place relating to space between positions in space. For a sphere and the spherical surface this is not so because measurement takes place not between positions intervened by space but along continuous presence of positions in the direction of measurement which is either curvilinear or curved

surface. The factor is, therefore, applicable to measurement in space of positions in which they exist in continuity in a continuum of positions having retained constant relationship with respect to some one position viz. the centre.

If this is so, then it is only applicable to configuration of positions in which distances between positions through positions having constant relationship relate to another position like centre of a sphere or a circular surface or circular orbit. There can be many like configurations. For example, with respect to apex of a cone a curved line comprising of positions can define a circular orbit. There also the factor should be applicable. Now is the question whether the same magnitude of (π) would be applicable to positions on the surface of the sphere as circumferential orbit on the spherical surface would also apply to elliptical surface and orbit of a cone.

Space Time Dimensional Significance of π

Let us continue the previous discussion further. Let us take one triangular face of 3 positions of the configuration of a regular tetrahedron. In figures 3(b) and 3(c) A, B and C are three positions. O is the centre of the tetrahedron. O' is the mid-point of the triangular face and P, Q, R are mid-points of the sides AB, BC, CA respectively. The triangular face is equilateral. Suppose the three positions A, B and C retaining their plane equilateral triangular structure converge towards mid-point O'. Ultimately, when the 3 positions converge to the point O' the three together form one position O'; but in imagination the concept of the three forming one point of position implies that O' in that state would be the point concept from which there

are three probabilities of development, viz. towards A, B and C. O' becomes a concept of point of position having three directional probability along O'A, O'B, O'C at a plane surface. These directions are at 120° angles to each other.

If, however, the configuration, instead of tetrahedron would be that of a spherical surface with respect to O the centre, the plane triangular face ABC would be converted into a spherical triangular surface abc in figure 3(d). On this spherical triangular surface abc the mid-point of the spherical triangular surface would be O₂. Following similar process as in the previous case if the positions a, b, c are converged retaining the constant radial distance OC, OB and OA towards the mid-position O₂ and at the same time retaining the same significance of equilateral curvilinear triangular characteristics of the position a, b, c at various stages, the three positions a, b, c will be merged at O₂ at one position. The three would thus become one point of position O₂ on the surface of sphere which would have properties of probabilities in three directions. These three directions however are curvilinear directions O₂a, O₂b, O₂c and any position along these, the radial distance from the centre O is constant. In figure 3(c) this distance from the centre of the tetrahedron varied from OC to the final converging point O' which means that the position retains equilateral characteristics but reduces in size of triangular on a plane surface. Their distances from the centre also get progressively reduced from OC=3 to OO'=1. In figure 3(d) when the positions a, b, c converge to one position O₂ although they retain their equilateral spherical triangular structural significance, the positions always retain constant distance from Oa, Ob, Oc, to OO₂=3.

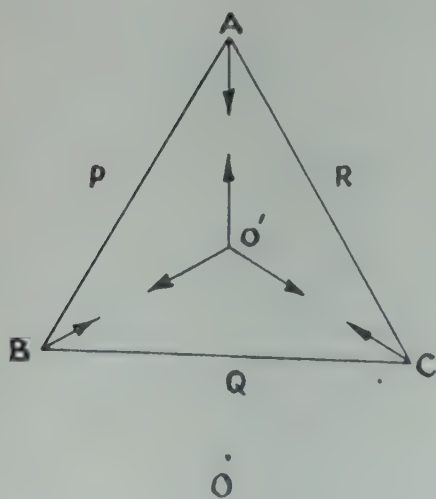


Fig. 3(b)

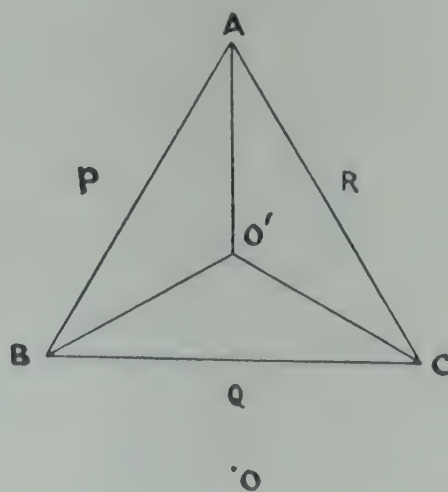


Fig. 3(c)

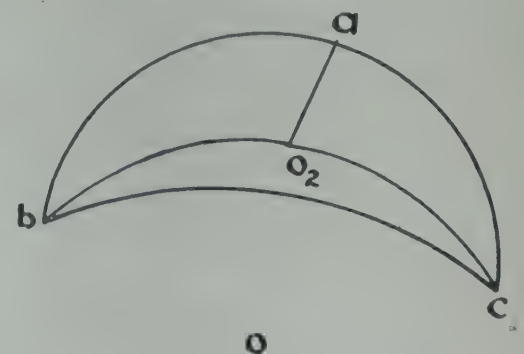


Fig. 3(d)

From figures 3(c) and 3(d) it would be clear that while three get converged to one position O_1 or O_2 they simultaneously change their positions in three directions such that: in the case of figure 3(c) while their own triangular surface configuration changes their own relative distance from O also changes; in case of figure 3(d) when the three positions change retaining their equilateral spherical triangular structure the distance of the positions from the centre O remains constant. If the two developments were considered with respect to the circle passing through the three positions ABC in figure 3(c) or a, b, c, in figure 3(d), as the circumferential orbits would vary between A, B, C and O' in figure 3(c) and a, b, c and O_2 in Fig. 3(d), the magnitudes of circumferential orbits in Fig. 3(c) would have varied in the same direction as the direction of variation of magnitudes of their distances from O , whereas in case of Fig. 3(d) as the size of the circumferential orbit reduces in size towards O_2 , the distance of the circumferential orbits from O would remain constant. Since the circumferential orbit dimensionally is T , in the case of Fig. 3(c), T/L would have started with maximum magnitude at ABC and minimum when the orbits through A, B, C converge to O' . In the case of Fig. 3(d), magnitude of T/L also would start with maximum value at a, b, c and reduce to minimum at O_2 though all along the magnitude of L remains constant.

Let us take a plane circular surface with centre at O_3 is Fig. 3(e). The size of circumferential orbit or the circular boundary can reduce in several ways towards one mid-position whose locus would be found on the perpendicular to the plane at O_3 [Fig. 3(f)]. The orbits could reduce along the plane surface itself. If, however, as in Fig. 3(f), the orbits while reducing in size their plane

would have also simultaneously raised perpendicularly so that their centres would have been always along O_3O_2 and if the orbits also would have described only locus of positions along the spherical surfaces, then the configuration at O_3 in Fig. (v) would have T maximum and L least. At O_2 T is least, L (which is O_3O_2) maximum. If instead of circular orbits describing the surface contour as in Fig. 3(f), the circular orbits would have described the surface of circular cone as in Fig. 3(g) and the centre positions of the orbits progressively would have described the perpendicular line O_3O_2 ; in this case, also L is least and T is maximum at O_3 and at the position O_2 , T is least and L is maximum. Like configurations 3(d) and 3(g), the radial distance of the orbits from O_3 in Fig. 3(f) remains constant during the variation of the orbits between the 2 states at O_2 and O_3 . Whereas in Fig. 3(g) the variation of the size of the orbits was also associated with the varying magnitudes of their distances from O_3 .

In Fig. 3(h) has been considered another mode of variation of L and T applicable to configuration of the either sphere, or ellipse or cube, or octahedron etc. in which the configuration as a whole must have two identical opposite positions. This would not be applicable to a regular tetrahedron. In Fig. 3(h) XX' divides the figures into two opposite halves. At O_3 , T is maximum and L is least, when L is perpendicular distance between centres of orbits. The variation of the orbits from O_3 to O_2 will have their centres lying on the perpendicular O_3O_2 . L/T at O_3 would be minimum and at O_2 would be maximum. Similarly, L/T , starting from minimum at O_3 is maximum at O'_2 .

From all these cases, it would appear that the dimensional concept of space 'L' as radial and dimensional

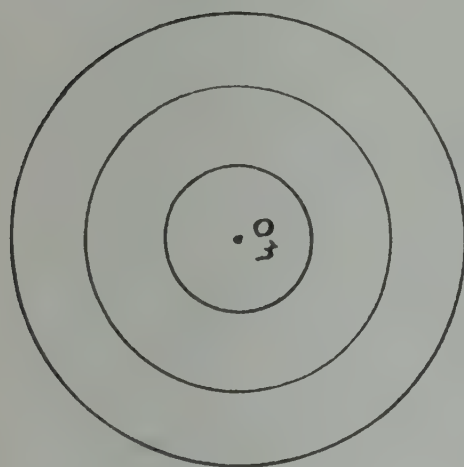


Fig. 3(e)

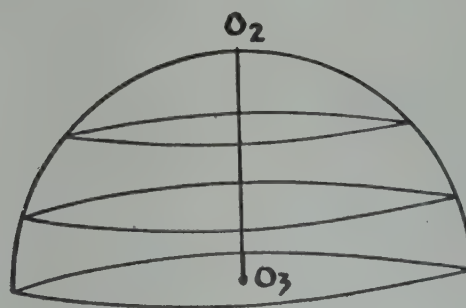


Fig. 3(f)

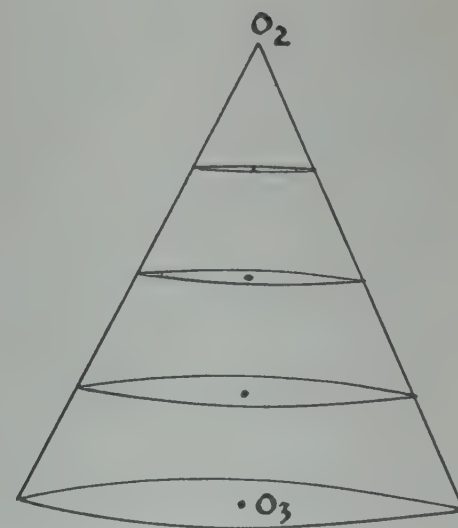


Fig. 3(g)

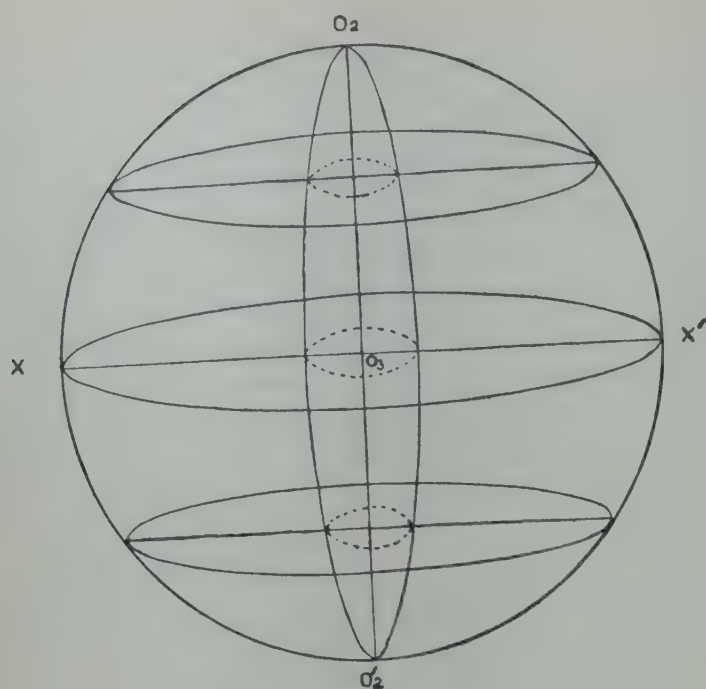


Fig. 3(h)

concept of time T as orbital, their relative magnitudes in configuration would depend on frame of reference of space and time with respect to reference position. If in case 3(h) the distance of orbit from centre is L , then L/T is minimum at O_3 and maximum at O_2 and O'_2 , though L of the orbits would remain constant. If, however, L is perpendicular distance of centre of orbits and O_3 the reference point, then L/T is minimum at O_3 and maximum at O_2 or O'_2 .

In all these cases the ratios of magnitudes of T , as size of the orbits and magnitude of L as their distance from reference point do not maintain constancy. They vary. At various stages in the developing configuration the magnitude of T/L assumes different magnitudes.

As against the above examples, let us take the case of circular orbits varying in size on a plane of paper between the centre and circular boundary. In this configuration in one plane the ratios of the size of the circular orbits to their corresponding distance from the centre retains constancy in magnitude at all the states, if we consider the development of spherical surfaces from a common centre. At various radial distances the ratio of the circumferential orbits of the spheres to corresponding radius bears a constant ratio whatever be the size of the sphere. In these cases if radius is L , the circumferential orbit is T . The magnitude of T/L in the latter two cases can be treated as absolute constant. But in configurations in which while the orbit varies in size with respect to reference point other than the centre of the orbit their relative ratios of magnitudes also vary.

From the above it would be clear that in configurations of space time coordinates in which space is radial and time is orbital, there can be many types of configurations having orbital and radial dimensions incorporated. The significance of π as an absolute constant and by definition as half of circumference/radius is only one particular type of space-time relationship in configuration. Essentially, dimension of π is T/L and is an absolute constant when T i.e. the magnitude of orbit varies with respect to its radial distance from its own centre. The variation of the orbit with respect to any other reference point will change this absolute constancy of T/L as π .

Space Time Relationships in the Configuration of Universal Spherical Wave and Regular Tetrahedron.

We shall proceed to discuss on the same lines as in the above the relationship in the tetrahedral configuration of the universal spherical wave. Adoption of the term "Spherical Wave" may cause some confusion. Since the configurations of the Universal wave between the centre and the boundary are figuratively composed of a central tetrahedron at whose 4 triangular faces 4 tetrahedrons are attached face to face so that the free corner positions of the outer four tetrahedrons would be located on the surface of imaginary spherical boundary having the radius of 5 units of distance from the centre of the central tetrahedron; and latter four positions would form the boundary of the spherical wave [Fig. 5(a), Evolution of the Science of Numbers and Mathematics of Magnitudes of Unit digits], hence this was termed as such.

In Tables 1 and 2 the various relationships in the evolving tetrahedral space configuration were developed out of positions in space in only one way i.e. only expansion. The opposite effect of contraction of space has not been discussed. The equilibrium configuration of the spherical wave is the resultant of tetrahedral configurations, in two opposing directions namely action of expansion due to central tetrahedron and the reaction as opposition to this action by four surrounding tetrahedrons in the spherical wave, as explained before, to restrict the development of magnitude of the central tetrahedron. In the equilibrium configuration, the central tetrahedron is opposed by four others to establish the equilibrium configuration of the spherical wave. In the central tetrahedron expansion of volume in four directions is opposed by 4 triangular faces. The evolved triangular faces thus act in opposition to volume expansion of the central tetrahedron. Each face acts in opposition to volume expansion in one direction from the centre.

It should be noted that the four other tetrahedrons lie in the heterogeneous zone of the spherical wave and the central tetrahedron lies within the homogeneous zone. The development of space from centre to the four corner positions of the central tetrahedron imparts property like momentum of space energy to the positions A, B, C and D. These positions do not possess any distinctive characteristics as mass of matter as distinct from space. The positions viz. $A_3C_2B_1$ in the heterogeneous zone, however relate to distinct matter characteristics from space. The space evolution first generates positions as ABCD as momentum or pressure or force of space itself. In the other tetrahedrons the positions have distinct matter significance in configurations. The positions say at $A_3C_2B_1$ with respect to the highest matter intensive position at X (which is at the boundary of the wave) have orbital momentum of the matter positions $A_3C_3B_1$.

We shall now analyse the mechanism of equilibrium of this universal configuration. To do so, one can separately consider each of the four outer tetrahedrons face to face with four triangular faces of the central tetrahedron, which means that each outer tetrahedron will be in equilibrium with one of the four central triangular pyramids, namely, OACD, OABD, ODCB and OBAC. In table 4 are listed the various magnitudes of dimensions of configuration (T. relative magnitudes of distances between positions in configuration) of the universal spherical wave. It would be seen from table 4 that each triangular pyramid from the centre towards a triangular face of the central tetrahedron has volume $2\sqrt{3}$ and the surface area of the triangular face is $2.3\sqrt{3}$. The corresponding volume of the outer tetrahedron which has maintained equilibrium of space development at one triangular surface of the central tetrahedron would be the volume described by 3 positions with respect to one at the boundary, which is the complete volume of the tetrahedron (having same magnitude of size as the central one) which is $8\sqrt{3}$ but the 3 positions at equilibrium describe only one triangular surface area equal to one triangular face of the central tetrahedron whose magnitude is $2.3\sqrt{3}$. The surface to volume ratio from the centre towards one triangular surface due to radial space evolution in one direction by the central configuration acts in opposition to the space volume and the triangular surface created by 3 positions $A_3C_2B_1$ with respect to one of the boundary positions say X.

We would apply the principle of equation of equilibrium as propounded in the theory of spherical wave (Introduction to Understanding of the Theory of

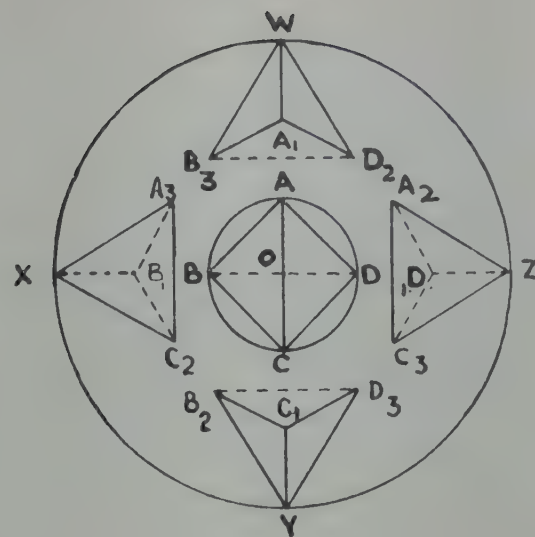


Fig. 4

Universal Spherical Wave of the "Energy Field of the Universe and Atom"). Equilibrium equation represents the equilibrium of action of one pair of opposites by reaction of opposite pair of opposites.

It was symbolically expressed as $+/- = -/+$. Applying this equation of equilibrium to the action of space volume of the central tetrahedron which would be opposed by triangular surfaces of the same configuration on the one hand and surface to volume ratio of central tetrahedron would be opposed by surface/volume ratio of outer tetrahedrons on the other to establish equilibrium configuration. Thus surface/volume ratio due to the central tetrahedron

in one direction = $\frac{2.3\sqrt{3}}{2\sqrt{3}}$ and surface to volume ratio

of one outer tetrahedron = $\frac{2.3\sqrt{3}}{8\sqrt{3}}$. The equilibrium

equation would be written as:

$$\frac{2.3\sqrt{3}}{2\sqrt{3}} = \frac{8\sqrt{3}}{2.3\sqrt{3}}$$

of central tetrahedron.

of outer tetrahedron

This would reduce to $(\sqrt{3}/\sqrt{2})^4 = \text{equilibrium constant } A_1$. If, however, the equation of equilibrium would be considered between the space volume only i.e. between the space volume enclosed within triangular pyramid OACD of the central tetrahedron it would oppose outer space volume $XC_2A_3B_1$, the two volumes having the common surface of contact namely, ACB or $A_3B_1C_2$.

In the equilibrium configuration, volume to volume

ratio in one direction namely OX, the equilibrium equation would be:

$$2\sqrt{3}=8\sqrt{3}\times\text{Eq. Constant.}$$

for which the equilibrium constant would be:

$$\frac{1}{2}=\left(\frac{1}{\sqrt{2}}\right)^4 \dots\dots\dots A_2.$$

It is needless to mention that the constants of equilibrium equations in the above relative to the equilibrium configuration viz. $(\sqrt{3}/\sqrt{2})^4$ and $(1/\sqrt{2})^4$ would be applicable to tetrahedral evolution of space, and the same equilibrium constants would also be valid when the space evolution is in four directions from centre.

If, instead of tetrahedron, the equilibrium would be considered between two opposing cones formed by the triangular pyramid OACB of the central tetrahedron and $XC_2A_3B_1$ the outer tetrahedron (as shown in the figure) having common circular plane orbital face, in the orbit of which the triangular positions ACB or $C_2A_3B_1$ would be always present. Thus the radius of this circular contact surface face between the two opposing cones would be:

$$\pi(2\sqrt{2})^2$$

Volume of the inner cone is:

$\pi/3 \times (2\sqrt{2})^2$ and volume of the outer opposing cone would be:

$$(\pi 4/3) \times (2\sqrt{2})^2$$

If now the surface to volume ratios of the cones are considered then the equilibrium equation between these two opposite ratios would be written as:

$$\frac{(2\sqrt{2})^2}{\pi/3(2\sqrt{2})^2} = \frac{\pi 4/3(2\sqrt{2})^2}{\pi(2\sqrt{2})^2}$$

(central cone) (outer cone)

The constant of equilibrium for this equation would reduce to:

$$\frac{(3)^2}{4} = \left(\frac{\sqrt{3}}{\sqrt{2}}\right)^4 \dots\dots\dots A_3$$

Just as it was done in the case of the tetrahedral mode previously in the above, if the equilibrium equation would be assumed to be established between the volume of the inner cone and the volume of the outer cone having the common face the corresponding equilibrium constant would be written as:

$$\frac{\pi(2\sqrt{2})^2}{\frac{4\pi}{3}(2\sqrt{2})^2} = 1/4 = \left(\frac{1}{\sqrt{2}}\right)^4 \dots\dots\dots A_4$$

Thus the equilibrium constants for the cones, of course, in a way having maintained the tetrahedral configuration fitting in the configuration of cone are the same as for the equilibrium constants relative to tetrahedral evolution of space. The configuration of the spherical wave, however, does not permit the applicability of the spherical configuration in the establishment of its equilibrium configuration (for reasons explained before).

Significance of Space Time Relationship in Geometrical Configurations

While regular tetrahedron is the least complicated, most isotropic and elementary configuration of positions in space, the sphere is a configuration of positions which is least isotropic. Tetrahedron has least number of positions evolved in space at constant radial distance from Centre. Sphere is the configuration of infinite number of positions or infinite number of probabilities of position being present anywhere at constant radial distance from the centre. The two states are extreme states of configuration of positions at constant distance from Centre. If the positions would generate various intermediate configurations of increasing numbers of positions between these two extreme configurations, then positions on the plane triangular face of the tetrahedron would undergo variation in their radial distances, 1 for centre to mid-positions of triangular surface faces of tetrahedron to 3 for centre to evolved positions on the surface of Sphere. Maximum radial variability would, therefore, be for the positions in Configuration corresponding to mid-points a, b, c and d of triangular plane surface faces and there would be no radial variation of positions of configurations between the extremes of the 4 evolved corner positions A, B, C and D of regular tetrahedron (a, b, c, d are mid-points of triangular surfaces say, a for face ABD, b for ABC, c for CBD and d for ACD).

The various typical positions relative to tetrahedral configuration will assume magnitude of 3 units in radial distance when the configuration of sphere will be generated of all positions at radial distance of 3 units from centre.

The mid-points of triangular faces which are at unit distance from the centre in the tetrahedral configuration would assume a magnitude of 3 when they will be lying on the spherical surface of radius 3. The distance from the centre to the mid-points of sides of tetrahedron which is $\sqrt{3}$ would become 3 when the mid-points of sides will coincide with the surface of the spherical configuration. The various radial distances

from the centre to the evolved positions of the tetrahedron namely A, B, C and D will however retain their positions at constant radial distance from the centre i.e. radially there would not be any variation of these positions in configuration between tetrahedron and sphere,

The relative distances between the positions in the configuration of tetrahedron would however change when these very positions would assume points of positions on the surface of sphere of radial distance of 3 units from centre. Thus, the distance between the mid-point on the plane triangular surface face of tetrahedral configuration to the mid-point of the sides [ap, Fig. 4(b)] which is $\sqrt{2}$ on the plane triangular surface will assume a magnitude of $\sqrt{3.2+(3-\sqrt{3})}$ when all the positions 'a' s and 'p' s will be on the surface of the sphere (distance as $\sqrt{2.3+(3-\sqrt{3})}$ will however not be curvilinear but straight distance in space between the positions a and p appearing on the surface of Sphere). The configuration that would be made of all the 6 'p' s on the surface of the sphere will be one of regular octahedron whose sides pp would have magnitude of $3\sqrt{2}$ and radial distances of positions from Centre would be 3. It may be recalled that $\sqrt{3}$ is the radial distance from the centre to mid point of evolved sides in a tetrahedron whereas $\sqrt{2}$ refers to the distance on the evolved surface from mid point of a triangular face to mid point of sides. In the evolved triangular face the distance from the mid surface to mid side is $\sqrt{2}$ and to corners is $2\sqrt{2}$, median is $3\sqrt{2}$. $\sqrt{2}$ is a factor which relates to directions along the evolved surface towards three positions of the triangle. Similarly, $\sqrt{3}$ is a factor which refers to radial direction from centre to 6 mid points of sides of tetrahedron and 1 or $\sqrt{1}$ refers to radial distance from centre to 4 mid-positions of a triangular face.

These factors, $1, \sqrt{2}, \sqrt{3}$ etc. relative to the configuration of tetrahedron, have outstanding significance towards reckoning of various dimensions of space and time relative to the various intermediate configurations between tetrahedron and sphere. Firstly, the digit 1 refers to 4 radial directions towards 4 positions in space as mid-points of the 4 triangular faces which have 3 directional probabilities of variation towards 3 corner positions along triangular surface and one radial direction. The digit 3 relates to again 3 directional probabilities towards 3 positions having no radial degree of freedom but the latter have each 3 degrees of freedom to 3 other positions. The factor $\sqrt{3}$ has 6 directional variabilities towards positions

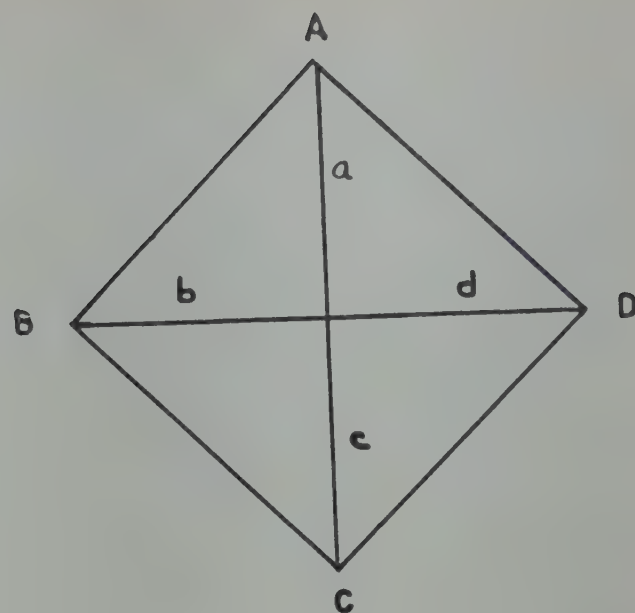


Fig. 4(a)

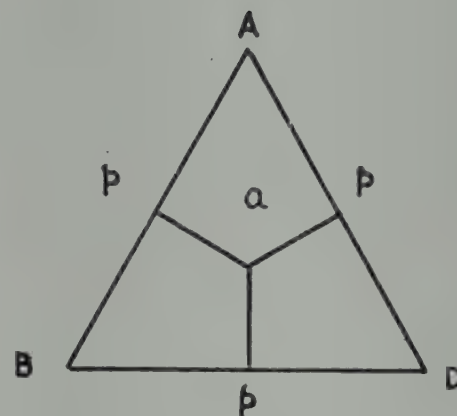


Fig. 4(b)

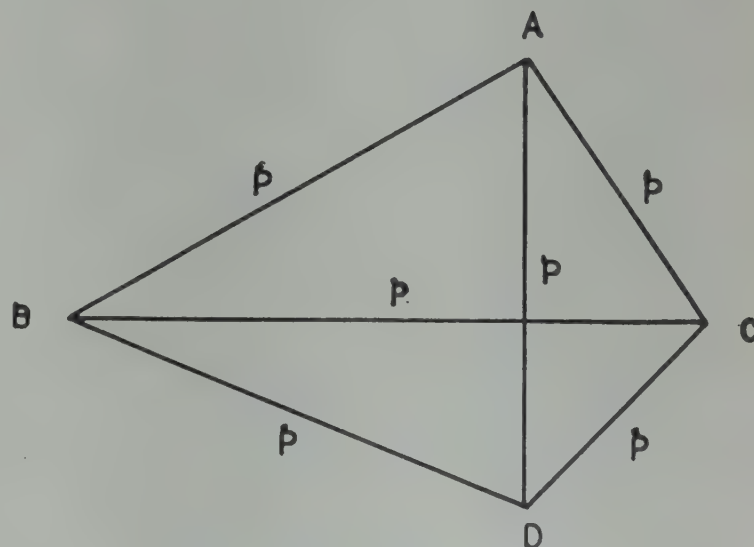


Fig. 4(c)

in configuration having 2 degrees of freedom. The six positions with respect to the centre forms a configuration of regular octahedron and these 6 radial directions are at right angles to each other at the centre. The factor $\sqrt{2}$ applies to a plane triangular surface of position in space having 4 directional probabilities, one perpendicular and 3 along plane surface. The digit 1 is radial four directional (having 4 dimensional significance) and 3 three directional, the former towards a position in space having 4 degrees and the latter towards positions having 3 degrees of freedom. The factor $\sqrt{3}$ has significance of rectangular coordinates ± 3 radial directions (3 dimensional coordinate) and $\sqrt{2}$ applies 4 directions, 3 relative to plane triangular coordinates along evolved surfaces and one perpendicular.

The factors $\sqrt{3}$ and $\sqrt{2}$ thus would have dimensional significance of space and time as L and T. This follows from dimensional significance of "Space as radial and time in configuration as orbital".

The equilibrium constants in the equilibrium configuration discussed before, in terms of space time relationship, would correspond to L^4/T^4 for A_1 and A_3 and $(1/T)^4$ for A_2 and A_4 . It may be seen in the above equilibrium equations that the left-hand side of equations A_1 and A_3 is $(\sqrt{3})^2$ i.e. square of space

dimension and on the right-hand side has dimension $\left[\frac{(\sqrt{2})^2}{\sqrt{3}}\right]^2$ which is Square of reciprocal of acceleration as $\left[\frac{T^2}{L}\right]^2$ This would be clear from the various space

time dimensional relationships which would be obtained in a tetrahedral spatial configuration which have been calculated and shown in the following table 8. The units of measurements follow the same principle as enunciated earlier.

In table 4, the various relative dimensional relationships have been listed as ratio of magnitude of one dimension to another in the unit configuration of tetrahedron. In calculating these distance between centre of the tetrahedron and mid-point of a triangular face has been employed as unit of distance. It may be seen from table 4 that the dimension of variability expressed as L/T in terms of space time dimensional relationship in the configuration of tetrahedron is the ratio of units of distance as side to the units of distance as altitude of the tetrahedron. Dimensional relationship as L/T also can be expressed as ratio of centre to mid-point of side to mid-point of face to mid point of side in the configuration of tetrahedron. Similarly, the ratio of the median to side of the tetra-

TABLE 4
Relative magnitudes of dimensions of regular tetrahedral configuration

Ratio of Median to Side	$\frac{3\sqrt{2}}{2\sqrt{2}\sqrt{3}} = \frac{\sqrt{3}}{2} = \frac{L}{T^2}$
„ „ Median to Altitude	$\frac{3\sqrt{2}}{4} = \frac{3}{3\sqrt{2}} = \frac{L^2}{T^3}$
„ „ Median/centre to corner position	$\frac{3\sqrt{2}}{3} = \sqrt{2} = T$
„ „ Side to Altitude	$\frac{2\sqrt{2}\sqrt{3}}{4} = \frac{\sqrt{3}}{\sqrt{2}} = L/T$
„ „ Central distance to mid side/Median	$\frac{\sqrt{3}}{3\sqrt{2}} = \frac{1}{\sqrt{2}\sqrt{3}} = 1/LT$
„ „ Central distance to Mid Side/Altitude	$\frac{\sqrt{3}}{4} = \frac{L}{T^4}$
„ „ Central distance to Mid Side/Side	$\frac{\sqrt{3}}{2\sqrt{2}\sqrt{3}} = 1/T^3$
„ „ Centre to Corner/Median	$\frac{3}{3\sqrt{2}} = 1/T$
„ „ Centre to Corner/Altitude	$\frac{3}{4} = \frac{L^2}{T^4} = \frac{(L)^2}{(T^2)}$
„ „ Centre to Corner/Side	$\frac{3}{2\sqrt{2}\sqrt{3}} = \frac{\sqrt{3}}{2\sqrt{2}} = \frac{L}{T^3}$
„ „ Centre to corner/Centre to mid Side	$\frac{3}{\sqrt{3}} = \sqrt{3} = L$

hedron can be expressed dimensionally as L/T^2 which is conventional dimension for acceleration. *In tetrahedral evolution of space the increase of size of configuration of space depends on the unit of distance chosen in terms of the various dimensions in the configuration of tetrahedron as side, median, altitude, etc. etc.*

If the unit of distance is 1 from the centre of the tetrahedron to mid-triangular face, in Table 1 it has been shown that the evolution of space governed by relationship as

$$\frac{L^2}{\text{magnitudes of units of distance in terms of distance from centre to mid-triangular face.}}$$

From table 1, we have seen that if the evolution of tetrahedral configuration would be expressed in terms of units of distance as from centre to the mid-triangular face of tetrahedron, then the surface to volume ratio of one triangular face and the triangular prism between the centre varies with increasing magnitude of distance from centre in terms of magnitudes of distance between the centre to mid-triangular face as

$$\frac{(\sqrt{3})^2}{\text{magnitude of distance between centre and the mid-triangular face.}}$$

Similarly, in table 2, it was seen that if the distance between the centre to any evolved position is taken as unit of distance, then the ratio of the surface of one triangular face/volume of one central triangular prism varies with increasing magnitude of distance from centre to the corner position of tetrahedron as:

$$\frac{(\sqrt{3})^4}{\text{distance from centre to evolved corner positions.}}$$

The significance of these relationships are of far-reaching importance, because the rate of increase of size of any configuration in space and time depends on the magnitude of unit of distance in space adopted with reference to the frame of configuration. Considering further in the context, the development of space assuming regular tetrahedral configuration, tables 5 to 13 have been constructed. Like tables 1 and 2 each of the tables from 5 to 12 compiles the calculated figures of numerical magnitudes of various dimensions of the tetrahedron in terms of any dimension as unit of distance in space. For example, in table 5, the magnitude of dimension has been calculated in terms of centre to mid triangular face as unit of distance. In table 6, the distance between the centre to corner position is assumed as unit of distance. In table 7, the figures are in terms of centre to mid-side of

TABLE 5—MAGNITUDES OF DIMENSIONS EXPRESSED IN TERMS OF CENTRE TO MID TRIANGULAR FACE AS UNITS OF DISTANCES

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Distance of centre to mid triangular face	Centre to corner position	Centre to Mid side	Altitude	Side	Mid face to corner	Mid face to Mid Side	Mid side to adjacent mid side	Mid side to mid Side opposite	Mid point of one face to Mid point of another face	Median of triangular face	Area of one triangular face	Total volume of tetrahedron	Surface to volume ratio	Dimensional relationship
Unit 1	1.3	1.√3	1.4	1.2√2/√3	1.2√2	1.√2	1.√2/√3	1.2√3	1.2√2/√3	1.3√2	1².2.3√3	1³.8√3	(3/4).1/1	L²/T⁴.1/1
2	2.3	2.√3	2.4	2.2√2/√3	2.2√2	2.√2	2.√2/√3	2.2√3	2.2√2/√3	2.3√2	2².2.3√3	2³.8√3	(3/4).1/2	L²/T⁴.1/2
3	3.3	3.√3	3.4	3.2√2/√3	3.2√2	3.√2	3.√2/√3	3.2√3	3.2√2/√3	3.3√2	3².2.3√3	3³.8√3	(3/4).1/3	L²/T⁴.1/3

TABLE 6—MAGNITUDE OF DIAMENSIONS EXPRESSED IN TERMS OF CENTRE TO CORNER POSITION
AS UNITS OF DISTANCES

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Distance of centre to mid-triangular face	Centre to corner position	Centre to mid side	Altitude	Side	Mid face to corner	Mid face to Mid Side	Mid side to adjacent mid side	Mid side to mid Side opposite	Mid point of one face to Mid point of another face	Median of triangular face	Area of one triangular face	Total volume of tetrahedron	Surface to volume ratio	Dimensional relationship
1/3	Unit	$1/3\sqrt{3}$	$(1/3).4$	$(1/3).2\sqrt{2}/3$	$(1/3).2\sqrt{2}$	$(1/3)\sqrt{2}/2$	$(1/3).\sqrt{2}/3$	$(1/3).2\sqrt{3}$	$(1/3).2\sqrt{2}/\sqrt{3}$	$(1/3).3\sqrt{2}$	$(1/3)^2.3\sqrt{3}$	$(1/3)^3.8\sqrt{3}$	$(3/4)^2.1/1$	$L^4/T^4.1/1$
2/3	2	$2/3\sqrt{3}$	$(2/3).4$	$(2/3).2\sqrt{2}/3$	$(2/3).2\sqrt{2}$	$(2/3)\sqrt{2}/2$	$(2/3)\sqrt{2}/3$	$(2/3).2\sqrt{3}$	$(2/3).2\sqrt{2}/\sqrt{3}$	$(2/3).3\sqrt{2}$	$(2/3)^2.3\sqrt{3}$	$(2/3)^3.8\sqrt{3}$	$(3/4)^2.1/2$	$L^4/T^4.1/2$
3/3	3	$3/3\sqrt{3}$	$(3/3).4$	$(3/3).2\sqrt{2}/3$	$(3/3).2\sqrt{2}$	$(3/3)\sqrt{2}/2$	$(3/3)\sqrt{2}/3$	$(3/3).2\sqrt{3}$	$(3/3).2\sqrt{2}/\sqrt{3}$	$(3/3).3\sqrt{2}$	$(3/3)^2.3\sqrt{3}$	$(3/3)^3.8\sqrt{3}$	$(3/4)^2.1/3$	$L^4/T^4.1/3$

tetrahedron as unit of distance. Similarly in tables 8, 9, 10, 11 etc. the figures have been calculated in terms of altitude side, median, mid-point of triangular face to mid-point of side, mid-face to corner positions respectively. In these tables (unlike tables 1 and 2 in which the area of one triangular face and volume of one triangular pyramid were taken into consideration), the area of one triangular face and volume of whole tetrahedron which is 4 times the volume of one triangular pyramid has been taken into account.

It may be seen from table 5 that if the surface to volume ratio is considered in terms of centre to mid-triangular face as unit of distance, the surface to volume ratio varies dimensionally as L^2/T^4 relative to increasing magnitudes of distance from the centre to mid-triangular face of the increasing configuration. From table 6, it may be seen that the same surface to volume ratio of the tetrahedron varies with respect to distance from centre to corner position as unit of distance relative to magnitudes of unit of distance from centre to corner position as L^4/T^4 . Similarly, from table 8, if altitude is the unit of distance then the surface to volume ratio varies relative to the magnitude of units of altitude as L^2 . If side of the tetrahedron would be unit of distance, then the variation of the surface volume ratio with respect to the side would be dimensionally L^3/T (Table 9). In terms of median, from table 15, the surface to volume ratio is L^4/T^3 . In terms of distance from centre to mid-side as unit table 7 the surface to volume ratio is L^3/T^4 . In terms of mid-point of triangular face to mid-point of side as unit, the surface-volume ratio is L^2/T^3 (Table 11). In terms of mid-point of face to corner position of a triangular face in table 10, the surface to volume ratio is L^2/T .

What was attempted to clarify was that in all the tables, the configuration is same i.e. that of regular tetrahedron but when the size of configuration varies (say, increases) in terms of magnitude of one dimension, the same varies with respect to unit magnitude of the relationship of one dimension as unit of distance and another relationship in terms of another dimension as unit of distance both in the same frame of reference, viz., tetrahedral configuration. All the tetrahedrons are constituted of the dimensions in terms of space and time.

All configurations of positions in space are generated at equilibrium due to action and reaction of space-time component-coordinates of positions in opposite phases with respect to reference point.

For the sake of simplicity, in the discussion which follows we shall confine ourselves to regular elementary

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
DISTANCE OF CENTRE TO MID TRIANGULAR FACE	CENTRE TO CORNER POSITION	CENTRE TO MID SIDE	ALTITUDE	SIDE	MID FACE TO C ORNER	MID FACE TO MID SIDE	MID SIDE TO ADJACENT MID SIDE	MID SIDE TO MID SIDE (OPPOSITE)	MID POINT OF ONE FACE TO MID POINT OF ANOTHER FACE	MEDIAN OF TRIANGULAR FACE	AREA OF ONE TRIANGULAR FACE	TOTAL VOLUME OF TETRAHEDRON	SURFACE TO VOLUME RATIO	DIMENSIONAL RELATIONSHIP

TABLE-7: MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF CENTRE TO MID SIDE AS UNITS OF DISTANCES

$\frac{1}{\sqrt{3}}$	$\frac{1}{\sqrt{3}} \cdot 3$	UNIT	$\frac{1}{\sqrt{3}} \cdot 4$	$\frac{1}{\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{1}{\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{1}{\sqrt{3}} \cdot \sqrt{2}$	$\frac{1}{\sqrt{3}} \cdot \sqrt{2}\sqrt{3}$	$\frac{1}{\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{1}{\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1}{\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{1}{\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{1}{\sqrt{3}})^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^4} \cdot \frac{1}{1}$	$\frac{L^3}{T^4} \cdot \frac{1}{1}$
$\frac{2}{\sqrt{3}}$	$\frac{2}{\sqrt{3}} \cdot 3$	2	$\frac{2}{\sqrt{3}} \cdot 4$	$\frac{2}{\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{2}{\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{2}{\sqrt{3}} \cdot \sqrt{2}$	$\frac{2}{\sqrt{3}} \cdot \sqrt{2}\sqrt{3}$	$\frac{2}{\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{2}{\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{2}{\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{2}{\sqrt{3}})^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^4} \cdot \frac{1}{2}$	$\frac{L^3}{T^4} \cdot \frac{1}{2}$
$\frac{3}{\sqrt{3}}$	$\frac{3}{\sqrt{3}} \cdot 3$	3	$\frac{3}{\sqrt{3}} \cdot 4$	$\frac{3}{\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{3}{\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{3}{\sqrt{3}} \cdot \sqrt{2}$	$\frac{3}{\sqrt{3}} \cdot \sqrt{2}\sqrt{3}$	$\frac{3}{\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{3}{\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{3}{\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{3}{\sqrt{3}})^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^4} \cdot \frac{1}{3}$	$\frac{L^3}{T^4} \cdot \frac{1}{3}$

TABLE-8 :- MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF ALTITUDE AS UNITS OF DISTANCES

	$\frac{1}{4} \cdot 3$	$\frac{1}{4} \sqrt{3}$	UNIT	$\frac{1}{4} \cdot 2\sqrt{2}\sqrt{3}$	$(\frac{1}{4}) \cdot 2\sqrt{2}$	$(\frac{1}{4}) \sqrt{2}$	$(\frac{1}{4}) \sqrt{2}\sqrt{3}$	$(\frac{1}{4}) \cdot 2\sqrt{3}$	$(\frac{1}{4}) \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$(\frac{1}{4}) \cdot 3\sqrt{2}$	$(\frac{1}{4})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{1}{4})^3 \cdot 8\sqrt{3}$	$(\sqrt{3})^2 \cdot \frac{1}{1}$	$L^2 \cdot \frac{1}{1}$
$\frac{1}{4}$	$\frac{1}{4} \cdot 3$	$\frac{1}{4} \sqrt{3}$	UNIT	$\frac{1}{4} \cdot 2\sqrt{2}\sqrt{3}$	$(\frac{1}{4}) \cdot 2\sqrt{2}$	$(\frac{1}{4}) \sqrt{2}$	$(\frac{1}{4}) \sqrt{2}\sqrt{3}$	$(\frac{1}{4}) \cdot 2\sqrt{3}$	$(\frac{1}{4}) \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$(\frac{1}{4}) \cdot 3\sqrt{2}$	$(\frac{1}{4})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{1}{4})^3 \cdot 8\sqrt{3}$	$(\sqrt{3})^2 \cdot \frac{1}{1}$	$L^2 \cdot \frac{1}{1}$
$\frac{2}{4}$	$\frac{2}{4} \cdot 3$	$\frac{2}{4} \sqrt{3}$	2	$\frac{2}{4} \cdot 2\sqrt{2}\sqrt{3}$	$(\frac{2}{4}) \cdot 2\sqrt{2}$	$(\frac{2}{4}) \sqrt{2}$	$(\frac{2}{4}) \sqrt{2}\sqrt{3}$	$(\frac{2}{4}) \cdot 2\sqrt{3}$	$(\frac{2}{4}) \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$(\frac{2}{4}) \cdot 3\sqrt{2}$	$(\frac{2}{4})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{2}{4})^3 \cdot 8\sqrt{3}$	$(\sqrt{3})^2 \cdot \frac{1}{2}$	$L^2 \cdot \frac{1}{2}$
$\frac{3}{4}$	$\frac{3}{4} \cdot 3$	$\frac{3}{4} \sqrt{3}$	3	$\frac{3}{4} \cdot 2\sqrt{2}\sqrt{3}$	$(\frac{3}{4}) \cdot 2\sqrt{2}$	$(\frac{3}{4}) \sqrt{2}$	$(\frac{3}{4}) \sqrt{2}\sqrt{3}$	$(\frac{3}{4}) \cdot 2\sqrt{3}$	$(\frac{3}{4}) \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$(\frac{3}{4}) \cdot 3\sqrt{2}$	$(\frac{3}{4})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{3}{4})^3 \cdot 8\sqrt{3}$	$(\sqrt{3})^2 \cdot \frac{1}{3}$	$L^2 \cdot \frac{1}{3}$

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
TABLE—9 :— MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF SIDE AS UNIT OF DISTANCE														
$\frac{1}{2\sqrt{2}\sqrt{3}}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 3$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{3}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 4$	UNIT	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{2}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}\sqrt{3}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{3}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 3\sqrt{2}$	$\frac{1}{2\sqrt{2}}\sqrt{3} \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{1}{2\sqrt{2}}\sqrt{3}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^3 \cdot \frac{1}{1}$	$\frac{1^3}{1} \cdot \frac{1}{1}$
$\frac{2}{2\sqrt{2}\sqrt{3}}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot 3$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{3}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot 4$	2	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{2}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}\sqrt{3}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{3}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{2\sqrt{2}}\sqrt{3} \cdot 3\sqrt{2}$	$\left(\frac{2}{2\sqrt{2}}\sqrt{3}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{2}{2\sqrt{2}}\sqrt{3}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^3 \cdot \frac{1}{2}$	$\frac{2^3}{1} \cdot \frac{1}{2}$
$\frac{3}{2\sqrt{2}\sqrt{3}}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot 3$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{3}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot 4$	3	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{2}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot \sqrt{2}\sqrt{3}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot 2\sqrt{3}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{2\sqrt{2}}\sqrt{3} \cdot 3\sqrt{2}$	$\left(\frac{3}{2\sqrt{2}}\sqrt{3}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{3}{2\sqrt{2}}\sqrt{3}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^3 \cdot \frac{1}{3}$	$\frac{3^3}{1} \cdot \frac{1}{3}$

TABLE—10 :— MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF MID FACE TO CORNER AS UNIT OF DISTANCE														
$\frac{1}{2\sqrt{2}}$	$\frac{1}{2\sqrt{2}} \cdot 3$	$\frac{1}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{1}{2\sqrt{2}} \cdot 4$	$\frac{1}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	UNIT	$\frac{1}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{1}{2\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{1}{2\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{1}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{3}$	$\frac{1}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{1}{2\sqrt{2}}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{1}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^2 \cdot \frac{1}{1}$	$\frac{1^2}{1} \cdot \frac{1}{1}$
$\frac{2}{2\sqrt{2}}$	$\frac{2}{2\sqrt{2}} \cdot 3$	$\frac{2}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{2}{2\sqrt{2}} \cdot 4$	$\frac{2}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	2	$\frac{2}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{2}{2\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{2}{2\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{2}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{2}{2\sqrt{2}}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{2}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^2 \cdot \frac{1}{2}$	$\frac{2^2}{1} \cdot \frac{1}{2}$
$\frac{3}{2\sqrt{2}}$	$\frac{3}{2\sqrt{2}} \cdot 3$	$\frac{3}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{3}{2\sqrt{2}} \cdot 4$	$\frac{3}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	3	$\frac{3}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{3}{2\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{3}{2\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{3}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{3}{2\sqrt{2}}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{3}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{2}\right)^2 \cdot \frac{1}{3}$	$\frac{3^2}{1} \cdot \frac{1}{3}$

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
TABLE -11 :- MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF MID FACE TO MID SIDE AS UNIT OF DISTANCE														
$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}} \cdot 3$	$\frac{1}{\sqrt{2}} \cdot \sqrt{3}$	$\frac{1}{\sqrt{2}} \cdot 4$	$\frac{1}{\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{1}{\sqrt{2}} \cdot 2\sqrt{2}$	UNIT	$\frac{1}{\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{1}{\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{1}{\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1}{\sqrt{2}} \cdot 3\sqrt{2}$	$(\frac{1}{\sqrt{2}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{1}{\sqrt{2}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^2 \cdot 3 \cdot \frac{1}{1}$	$\frac{L^2}{T^3} \cdot \frac{1}{1}$
$\frac{2}{\sqrt{2}}$	$\frac{2}{\sqrt{2}} \cdot 3$	$\frac{2}{\sqrt{2}} \cdot \sqrt{3}$	$\frac{2}{\sqrt{2}} \cdot 4$	$\frac{2}{\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{2}{\sqrt{2}} \cdot 2\sqrt{2}$	2	$\frac{2}{\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{2}{\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{2}{\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{\sqrt{2}} \cdot 3\sqrt{2}$	$(\frac{2}{\sqrt{2}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{2}{\sqrt{2}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^2 \cdot 3 \cdot \frac{1}{2}$	$\frac{L^2}{T^3} \cdot \frac{1}{2}$
$\frac{3}{\sqrt{2}}$	$\frac{3}{\sqrt{2}} \cdot 3$	$\frac{3}{\sqrt{2}} \cdot \sqrt{3}$	$\frac{3}{\sqrt{2}} \cdot 4$	$\frac{3}{\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{3}{\sqrt{2}} \cdot 2\sqrt{2}$	3	$\frac{3}{\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{3}{\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{3}{\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{\sqrt{2}} \cdot 3\sqrt{2}$	$(\frac{3}{\sqrt{2}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{3}{\sqrt{2}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^2 \cdot 3 \cdot \frac{1}{3}$	$\frac{L^2}{T^3} \cdot \frac{1}{3}$
TABLE -12 :- MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF MID SIDE TO ADJACENT MID SIDE														
$\frac{1}{\sqrt{2}\sqrt{3}}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 3$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot \sqrt{3}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 4$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot \sqrt{2}$	UNIT	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{1}{\sqrt{2}\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{1}{\sqrt{2}\sqrt{3}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^3 \cdot 3 \cdot \frac{1}{1}$	$\frac{L^3}{T^3} \cdot \frac{1}{1}$
$\frac{2}{\sqrt{2}\sqrt{3}}$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 3$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot \sqrt{3}$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 4$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot \sqrt{2}$	2	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{\sqrt{2}\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{2}{\sqrt{2}\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{2}{\sqrt{2}\sqrt{3}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^3 \cdot 3 \cdot \frac{1}{2}$	$\frac{L^3}{T^3} \cdot \frac{1}{2}$
$\frac{3}{\sqrt{2}\sqrt{3}}$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 3$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot \sqrt{3}$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 4$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{1}{\sqrt{2}\sqrt{3}} \cdot \sqrt{2}$	3	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{\sqrt{2}\sqrt{3}} \cdot 3\sqrt{2}$	$(\frac{3}{\sqrt{2}\sqrt{3}})^2 \cdot 2 \cdot 3\sqrt{3}$	$(\frac{3}{\sqrt{2}\sqrt{3}})^3 \cdot 8\sqrt{3}$	$(\frac{\sqrt{3}}{\sqrt{2}})^3 \cdot 3 \cdot \frac{1}{2}$	$\frac{L^3}{T^3} \cdot \frac{1}{2}$

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
TABLE - 13 :- MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF MID SIDE TO OPPOSITE MID SIDE AS UNIT OF DISTANCE														
$\frac{1}{2\sqrt{3}}$	$\frac{1}{2\sqrt{3}} \cdot 3$	$\frac{1}{2\sqrt{3}} \cdot \sqrt{3}$	$\frac{1}{2\sqrt{3}} \cdot 4$	$\frac{1}{2\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{1}{2\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{1}{2\sqrt{3}} \cdot \sqrt{2}$	$\frac{1}{2\sqrt{3}} \cdot \sqrt{2\sqrt{3}}$	UNIT	$\frac{1}{2\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1}{2\sqrt{3}} \cdot 3\sqrt{2}$	$\left(\frac{1}{2\sqrt{3}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{1}{2\sqrt{3}}\right)^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^2} \cdot \frac{1}{1}$	$\frac{L^3}{T^2} \cdot \frac{1}{1}$
$\frac{2}{2\sqrt{3}}$	$\frac{2}{2\sqrt{3}} \cdot 3$	$\frac{2}{2\sqrt{3}} \cdot \sqrt{3}$	$\frac{2}{2\sqrt{3}} \cdot 4$	$\frac{2}{2\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{2}{2\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{2}{2\sqrt{3}} \cdot \sqrt{2}$	$\frac{2}{2\sqrt{3}} \cdot \sqrt{2\sqrt{3}}$	2	$\frac{2}{2\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2}{2\sqrt{3}} \cdot 3\sqrt{2}$	$\left(\frac{2}{2\sqrt{3}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{2}{2\sqrt{3}}\right)^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^2} \cdot \frac{1}{2}$	$\frac{L^3}{T^2} \cdot \frac{1}{2}$
$\frac{3}{2\sqrt{3}}$	$\frac{3}{2\sqrt{3}} \cdot 3$	$\frac{3}{2\sqrt{3}} \cdot \sqrt{3}$	$\frac{3}{2\sqrt{3}} \cdot 4$	$\frac{3}{2\sqrt{3}} \cdot 2\sqrt{3}$	$\frac{3}{2\sqrt{3}} \cdot 2\sqrt{2}$	$\frac{3}{2\sqrt{3}} \cdot \sqrt{2}$	$\frac{3}{2\sqrt{3}} \cdot \sqrt{2\sqrt{3}}$	3	$\frac{3}{2\sqrt{3}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3}{2\sqrt{3}} \cdot 3\sqrt{2}$	$\left(\frac{3}{2\sqrt{3}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{3}{2\sqrt{3}}\right)^3 \cdot 8\sqrt{3}$	$\frac{(\sqrt{3})^3}{(\sqrt{2})^2} \cdot \frac{1}{3}$	$\frac{L^3}{T^2} \cdot \frac{1}{3}$

TABLE - 14: MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF ONE MID FACE TO ANOTHER MID FACE AS UNIT OF DISTANCE

$\frac{1\sqrt{3}}{2\sqrt{2}}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot 3$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot 4$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2\sqrt{3}}$	UNIT	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{1\sqrt{3}}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{1\sqrt{3}}{2\sqrt{2}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{1\sqrt{3}}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\frac{\sqrt{3}}{\sqrt{2}} \cdot \frac{1}{1}$	$\frac{L}{T} \cdot \frac{1}{1}$
$\frac{2\sqrt{3}}{2\sqrt{2}}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot 3$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot 4$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2\sqrt{3}}$	2	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{2\sqrt{3}}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{2\sqrt{3}}{2\sqrt{2}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{2\sqrt{3}}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\frac{\sqrt{3}}{\sqrt{2}} \cdot \frac{1}{2}$	$\frac{L}{T} \cdot \frac{1}{2}$
$\frac{3\sqrt{3}}{2\sqrt{2}}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot 3$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{3}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot 4$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot \sqrt{2\sqrt{3}}$	3	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	$\frac{3\sqrt{3}}{2\sqrt{2}} \cdot 3\sqrt{2}$	$\left(\frac{3\sqrt{3}}{2\sqrt{2}}\right)^2 \cdot 2.5\sqrt{3}$	$\left(\frac{3\sqrt{3}}{2\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\frac{\sqrt{3}}{\sqrt{2}} \cdot \frac{1}{3}$	$\frac{L}{T} \cdot \frac{1}{3}$

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
TABLE 15 MAGNITUDE OF DIMENSIONS EXPRESSED IN TERMS OF MEDIAN OF TRIANGULAR FACE AS UNIT OF DISTANCE														
$\frac{1}{3\sqrt{2}}$	$\frac{1}{3\sqrt{2}} \cdot 3$	$\frac{1}{3\sqrt{2}} \cdot \sqrt{3}$	$\frac{1}{3\sqrt{2}} \cdot 4$	$\frac{1}{3\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{1}{3\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{1}{3\sqrt{2}} \cdot \sqrt{2}$	$\frac{1}{3\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{1}{3\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{1}{3\sqrt{2}} \cdot \frac{2\sqrt{3}}{\sqrt{3}}$	UNIT	$\left(\frac{1}{3\sqrt{2}}\right)^2 \cdot 3\sqrt{3}$	$\left(\frac{1}{3\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{\sqrt{2}}\right)^4 \cdot \frac{1}{1}$	$\frac{L^4}{T^3} \cdot \frac{1}{1}$
$\frac{2}{3\sqrt{2}}$	$\frac{2}{3\sqrt{2}} \cdot 3$	$\frac{2}{3\sqrt{2}} \cdot \sqrt{3}$	$\frac{2}{3\sqrt{2}} \cdot 4$	$\frac{2}{3\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{2}{3\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{2}{3\sqrt{2}} \cdot \sqrt{2}$	$\frac{2}{3\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{2}{3\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{2}{3\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	2	$\left(\frac{2}{3\sqrt{2}}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{2}{3\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{\sqrt{2}}\right)^4 \cdot \frac{1}{2}$	$\frac{L^4}{T^3} \cdot \frac{1}{2}$
$\frac{3}{3\sqrt{2}}$	$\frac{3}{3\sqrt{2}} \cdot 3$	$\frac{3}{3\sqrt{2}} \cdot \sqrt{3}$	$\frac{3}{3\sqrt{2}} \cdot 4$	$\frac{3}{3\sqrt{2}} \cdot 2\sqrt{2}\sqrt{3}$	$\frac{3}{3\sqrt{2}} \cdot 2\sqrt{2}$	$\frac{3}{3\sqrt{2}} \cdot \sqrt{2}$	$\frac{3}{3\sqrt{2}} \cdot \sqrt{2}\sqrt{3}$	$\frac{3}{3\sqrt{2}} \cdot 2\sqrt{3}$	$\frac{3}{3\sqrt{2}} \cdot \frac{2\sqrt{2}}{\sqrt{3}}$	3	$\left(\frac{3}{3\sqrt{2}}\right)^2 \cdot 2 \cdot 3\sqrt{3}$	$\left(\frac{3}{3\sqrt{2}}\right)^3 \cdot 8\sqrt{3}$	$\left(\frac{\sqrt{3}}{\sqrt{2}}\right)^4 \cdot \frac{1}{3}$	$\frac{L^4}{T^3} \cdot \frac{1}{3}$

configurations only and we shall also confine ourselves to the most elementary configuration of regular tetrahedron to start with and discuss generation of universal wave, cube and octahedron and the various coordinates that are involved in their transformations.

In the configurations, the coordinates with respect to reference point to the positions in space are of two opposite directions. Directions of variability of the positions could be from or towards the reference point. For example from an imaginary point concept of 4 positions having imaginary tetrahedral configuration at O, when the 4 positions emanate describing progressively bigger configurations of regular tetrahedrons, the positions emanate radially from the centre describing the configurations.

The coordinates from the centre towards evolved positions emanate or diverge from the centre. Example of converging type may be explained as follows. Consider one position of a regular tetrahedron, A, as the reference point and the 3 other positions B, C and D may vary towards the position A, the size of the tetrahedron progressively becomes [Fig. 5(b)] smaller but at every stage retains the regular tetrahedral structure. In the process, along the coordinates BA, CA, DA, the positions progressively reduce in their magnitudes of coordinates from B, C and D to A till the four positions merge into one at A having imaginary tetrahedral structure of positions in which the 4 positions reduce to one position with 3 probabilities. In the previous case coordinates from A,B,C and D would converge to O, a point with 4 probabilities.

In the description of the universal wave configuration of tetrahedral equilibrium, the configuration has one central regular tetrahedron, the four triangular faces of which are attached to 4 regular tetrahedrons and the free corners of which (W, X, Y and Z) form 4 positions equidistant from the centre of the central tetrahedron and form the boundary of the spherical wave Fig. 5(c).

The space-time configurational evolution starts from the centre of the central tetrahedron with 4 probabilities or 4 directional tetrahedral coordinates OA, OB, OC, and OD towards A, B, C and D. From each triangular face of the central tetrahedron, 4 sets of three-directional component coordinates, one set each from ABC, ACD, BCD, ABD converge to W, X, Y and Z positions, which form the boundary of the universal configuration. From the centre the 4 positions emanate along 4 coordinates, the angle between any two at the centre being 109° . We have called this as the tetrahedral coordinate. The coordinates towards any 3

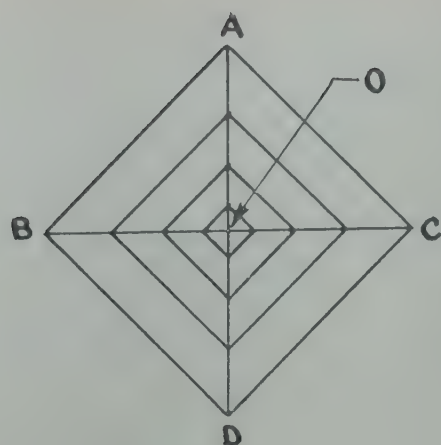


Fig. 5(a)

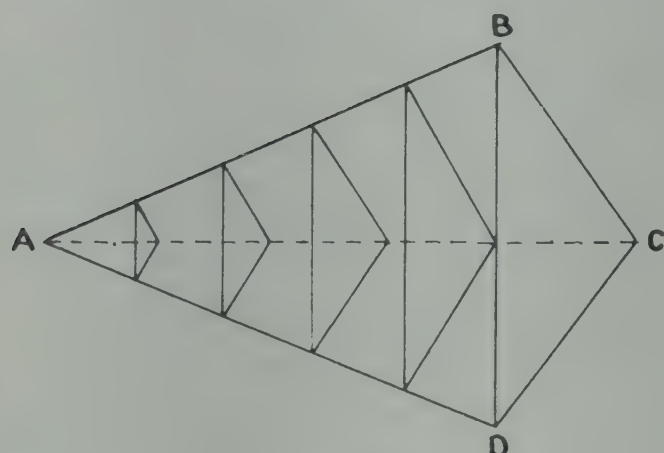


Fig. 5(b)

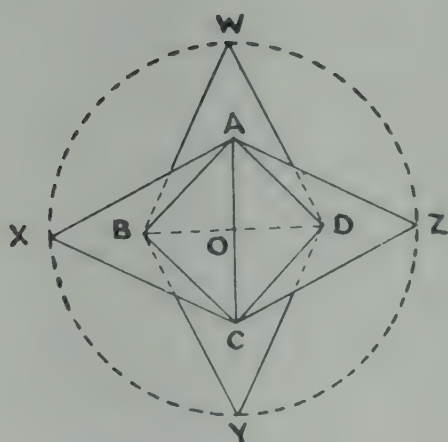


Fig. 5(c)

of the 4 evolved positions make a triangular pyramid, the base triangle of which is one isosceles triangular face, say A B C of the tetrahedron and the 3 triangular side faces of the pyramid bounded by the coordinates as OA, OB, OC make 109° at the centre. The co-ordinates from the centre diverge towards A, B, C and D but from each of the triangular faces of the central tetrahedron ABCD, the three component coordinates from 3 positions converges towards boundary posi-

tions W, X, Y and Z, where the coordinates make 60° angle with each other at the boundary positions. We shall call this as the 60° coordinate which is the three-directional coordinate with respect to one position on the evolved tetrahedron towards other three positions and the direction of the coordinate can be from one position towards the rest 3 positions of regular tetrahedron and vice versa.

Taking the universal configuration thus, the equilibrium configuration in one direction is between one full outer tetrahedron face to face with one of the 4 triangular pyramids of the central tetrahedron. In one direction, the centre O of the central tetrahedron is the position of point of reference from which the tetrahedral coordinates emanate and forms equilibrium configuration in one direction with three, 60° coordinates, converging to one of the 4 positions W, X, Y and Z at the boundary. The equilibrium configuration in one direction, thus, can be considered as one of the 4 component configurations, each generated from one three-directional tetrahedral coordinates from the centre O towards 3 positions say, ABC which establish equilibrium with three directional 60° coordinates from one of the 4 boundary positions as reference point for the latter coordinates. There are 4 such directions in the universal equilibrium configuration and 4 such component configurations define the equilibrium configuration of the universal wave.

Coordinates in the Configuration of Octahedron and Cube

When two 3-directional 60° coordinates to 3 positions from a reference point is in equilibrium between two opposite phases, such that the reference point in one phase becomes the mid-point of triangular face of the 3 positions in the opposite phases, the resulting configuration becomes octahedron. The mechanism can be also stated in another way.

When 4 positions of a regular tetrahedron vibrates between opposite phases such that the distance between the two mid-points of the 3 positions in opposite phases retain the same magnitude of distance as altitude of the tetrahedron the 6 positions describe the configuration of octahedron. It has been shown that in the equilibrium configuration of octahedron, the centre of equilibrium of the two pairs of 3 positions in opposite phases is at mid-point of distance between the mid-points of triangular faces of 3 positions in opposite phases. The coordinates of positions to this mid-point O_1 are at right angles to one another. The triangular pyramids $O_1 BCD$ and $O_1 bcd$ are rectangular coordinates i.e. the coordinates namely, $O_1 B, O_1 C$

and O_1D which are sides of the triangular pyramid make right angles at O_1 [Fig. 5(d)].

Regarding configuration of cube, we have shown before that the constitution of the configuration of cube in terms of coordinates of positions is exactly opposite to that of octahedral configuration. For example, cube is an equilibrium configuration of three directional rectangular coordinates to 3 positions when vibrates in opposite phases such that the reference points in the case of the cube are two, each of which belongs to one phase with coordinates to three positions belonging to opposite phase. In the octahedron, the reference position is one which is also the centre of the configuration. In the case of cube the reference positions are two opposite corners. The configuration of cube can be described as resultant configuration in which 4 tetrahedral positions vibrate between opposite phases, retaining fixed centre for both the phases.

It is now intended to describe the configuration in terms of space and time coordinates. The configuration of positions in terms of the space and time dimensional coordinates may be described in many ways. From the tables 1 to 14 as well as list 8 it would be seen that the elementary configuration of tetrahedron itself can be described dimensionally in terms of its various dimensions, it may be the side or central distance to corner, median of triangular face or altitude and so on and so forth. It can also dimensionally be described in terms of surface or volume or in terms of surface to volume ratio. We have chosen however, in the present discussion, the generation of equilibrium configuration of positions by the coordinates employing surface to volume ratio generally. Other dimensions also could have been used and perhaps more simpler relationships could be obtained.

For illustrative purposes, the following examples are cited to explain our view point further. In the configuration of tetrahedron it has certain volume and it has 4 faces; but all the coordinates leading to 4 positions from the centre may or may not be active. Say if one triangular face of the tetrahedron is active that means the tetrahedron, although its total volume is retained but only one triangular surface, is active. Only 3 tetrahedral coordinates to 3 positions from the centre are operative. In such a case, let us calculate surface-volume ratio in terms of distance from centre to mid face as unit of distance which we have described before. The volume of tetrahedron is $4.2\sqrt{3}$ and area of one triangular surface face is $2.3\sqrt{3}$. Surface to volume ratio is $3/4$ which in terms of space-time dimensions can be dimensionally

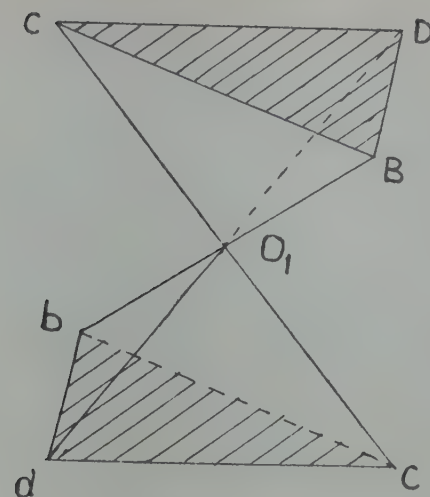


Fig. 5(d)

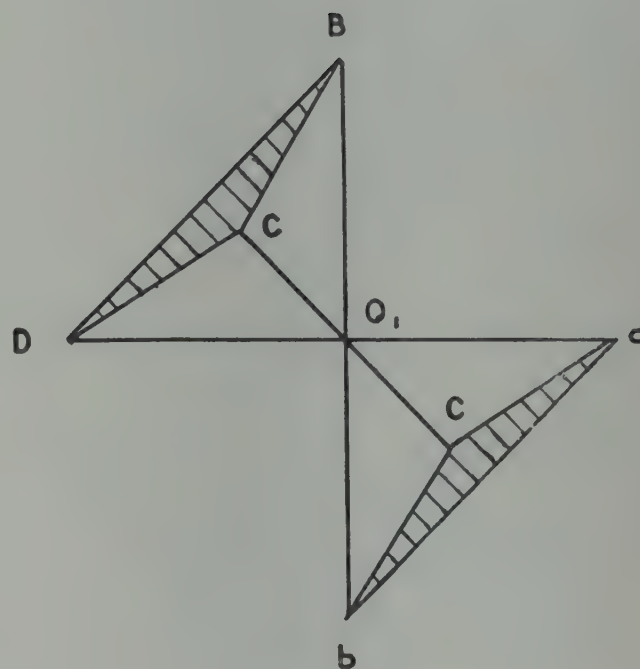


Fig. 5(e)

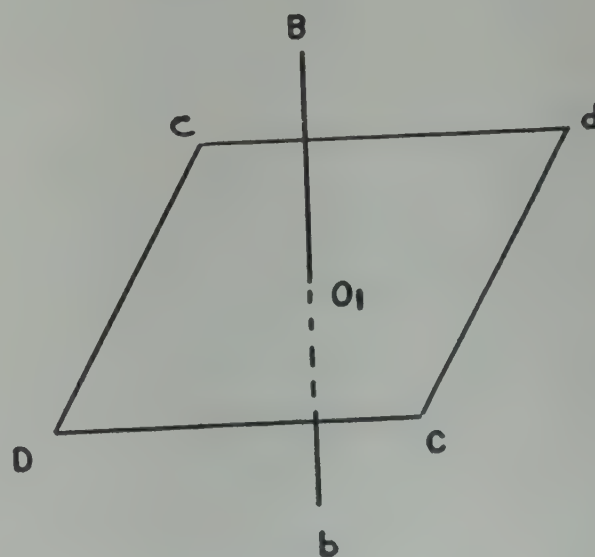


Fig. 5(f)

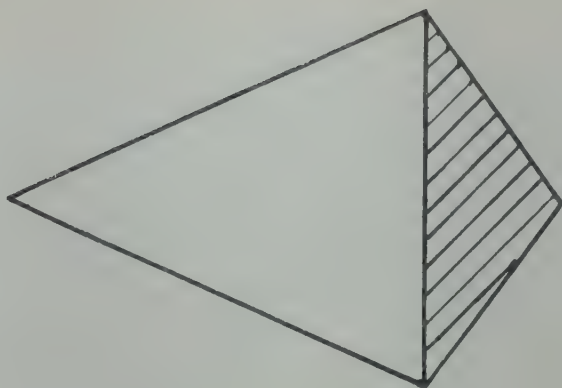


Fig. 5(g)

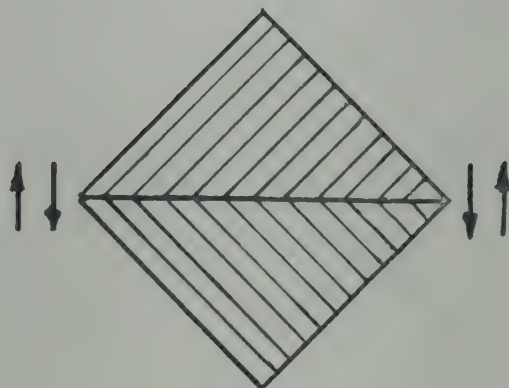


Fig. 5(h)

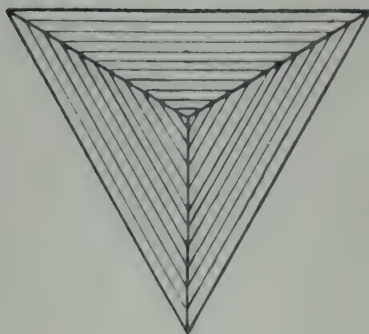


Fig. 5(i)

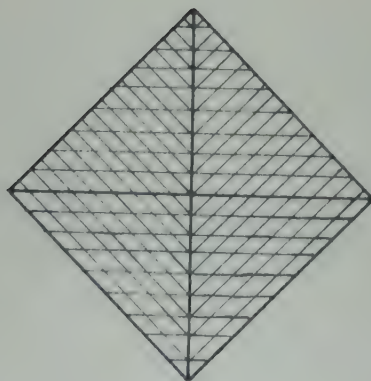


Fig. 5(j)

expressed as L^2/T^4 . If, however, for one active triangular face only volume corresponding to that of one triangular pyramid as OABC of central tetrahedron

is active, the surface volume ratio is $\frac{2.3\sqrt{3}}{2\sqrt{3}} = 3$ or dimensionally this is L^2 . The surface to volume ratio of the configuration of tetrahedron depends on the coordinates which are active. The various functioning of the space-time relationship in the configuration of regular tetrahedron is shown below.

Configuration of Tetrahedron

The configuration of tetrahedron can be active in 4 different manners:

(1) Only one of its faces could be active but whole volume is active.

$$\frac{\text{Surface}}{\text{Volume}} \text{ is } \frac{2.3\sqrt{3}}{4.2\sqrt{3}} = 3/4$$

Dimensionally $3/4$ is L^2/T^4 (Dimensionally, this is square of dimension as acceleration as $(L/T^2)^2$. The dimension of acceleration as L/T^2 can be realised from the configuration of octahedron. (Since $\sqrt{2}$ is T and $\sqrt{3}$ is L).

(2) Two faces may be active and whole volume active.

$$\frac{\text{Surface}}{\text{Volume}} = \frac{2 \text{ face}}{\text{volume}} = \frac{2.2.3\sqrt{3}}{4.2\sqrt{3}} = 3/2$$

Dimensionally L^2/T^2

(3) Three faces and whole volume active.

$$\frac{\text{Surface}}{\text{Volume}} = \frac{3.2.3\sqrt{3}}{4.2\sqrt{3}} = 3^2/4 = L^4/T^4$$

(4) If all the 4 faces of the tetrahedron would be active like the central tetrahedron of the universal spherical wave, then:

$$\frac{\text{Surface}}{\text{Volume}} = \frac{4.2.3\sqrt{3}}{4.2\sqrt{3}} = 3 = L^2$$

Constancy of Space-time Relationships of Coordinates in the Equilibrium Configurations

We shall now consider the relationships of space-time coordinates in the configurations of universal wave, cube and octahedron. All equilibrium configurations are resultants of component configurations.

We will take first the equilibrium configuration of the universal wave. We have already discussed this before that the universal equilibrium configuration in *one direction* of the wave is one generated as a result of reaction and action between one 3-directional 60° coordinate from a position at the boundary of the wave in opposition to a 3-directional tetrahedral coordinate from the centre of the wave. This is in one direction. The total equilibrium configuration of the universal wave is, however, having 4-directional probability from the centre. The definition of this total configuration in terms of the coordinate would be:

A configuration generated as a result of reaction and action of four 3 directional 60° coordinates from 4 positions at the boundary of the wave acting in opposition to one 4-directional tetrahedral coordinate to 4 positions from the centre. In the following as an illustration deduction of equilibrium constants in terms of space-time dimensional relationships in the universal configuration has been shown below:

Configuration of universal wave as one central regular tetrahedron with 4 regular tetrahedrons.

Calculation of surface volume ratios:

$$\text{Surface ABC} = 2.3\sqrt{3}$$

$$\text{Vol XABC} = 4.2\sqrt{3}$$

$$\text{Vol OABC} = 2\sqrt{3}$$

Surface volume reaction between three directional 60° and 109° coordinates in equilibrium is expressed as:

$$\frac{\frac{\text{ABC}}{\text{OABC}}}{\text{Or } \frac{2.3\sqrt{3}}{2\sqrt{3}}} = \frac{V_s}{V_s} \frac{\frac{\text{XABC}}{\text{ABC}}}{\frac{4.2\sqrt{3}}{2.3\sqrt{3}}}$$

$$\text{Eq. constant is } \frac{2.3\sqrt{3} \cdot 2.3\sqrt{3}}{4.2\sqrt{3} \cdot 2\sqrt{3}} = \frac{3^2}{4}$$

Expressed dimensionally, the constant is L^4/T^4 , which is one direction. For the whole configuration involving 4 directions, the equilibrium constant would be $(L^4/T^4)^4$ or L^{16}/T^{16} .

It may be noticed from the deduction of space-time relationship in the configuration of the universal spherical wave that the reaction between 3 directional tetrahedral coordinate from the centre with 3 directional 60° coordinate from the boundary gives a constant dimensional relationship for the component equilibrium configuration in one direction of the spherical wave as $(L/T)^4$. If the total configuration would be taken into account incorporating 4 directional probabilities, the constant of dimensional relationship would be $(L/T)^{16}$.

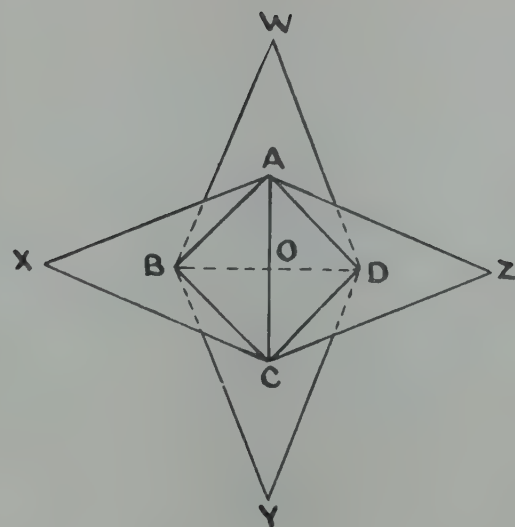


Fig. 5(k)

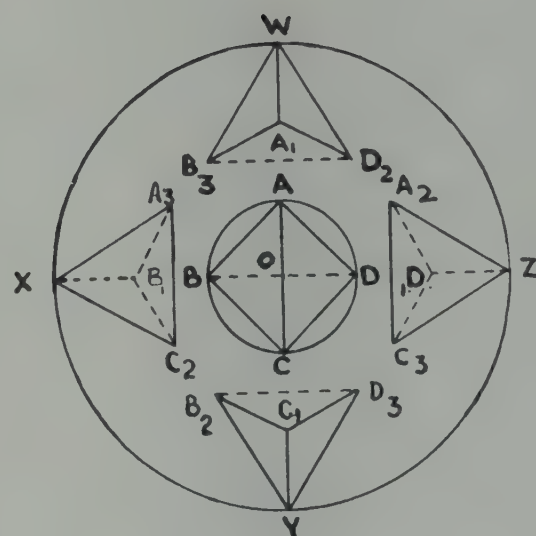


Fig. 5(l)

The letters correspond in the two figures.

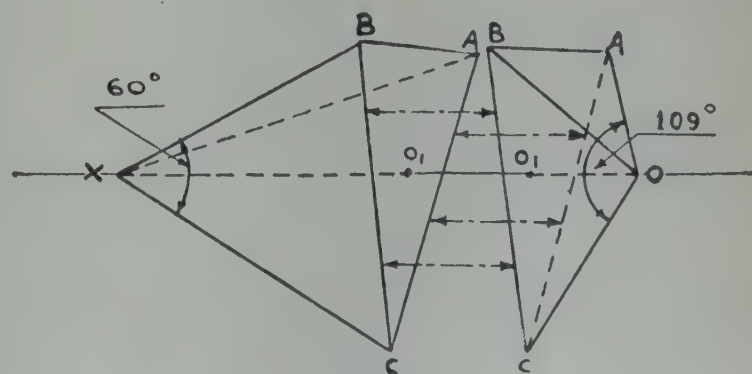


Fig. 5(m)

O is centre of tetrahedron ABD one triangular face OABD triangular prism with three directional tetrahedral coordinates OA, OB and OD.

Component configuration in one direction.

Constancy of space-time relationships of coordinates in the configuration of Cube

Configuration of cube is one which is formed by a central regular tetrahedron to the equilateral triangular faces of which are added 4 regular rectangular triangular pyramids each having same triangular base as that of the central tetrahedron. (In the universal configuration instead of rectangular triangular pyramids these were 60 triangular pyramids.) The configuration of the cube should be visualised as in Figs. 5(n), 5(o) and 5(d) Magnitudes of important dimensions of the configuration:

Centre to corner positions	$= 3$
Centre mid sq. face	$= \sqrt{3}$
Side	$= 2\sqrt{3}$
Diagonal of sq. face	$= 2\sqrt{2}\sqrt{3}$

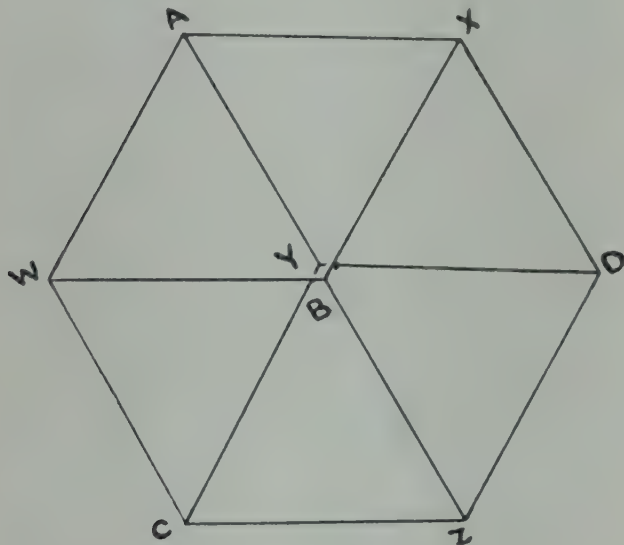


Fig. 5(n)
Whole configuration of cube.

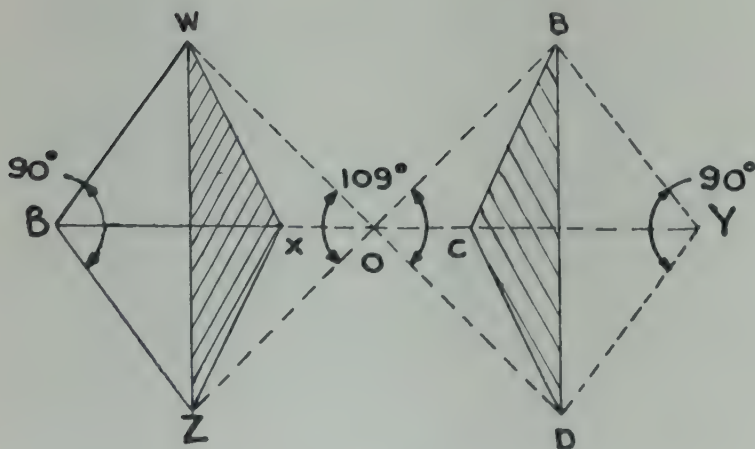


Fig. 5(o)
Triangular pyramid with rectangular Coordinates.
Component configurations making the configuration of cube.

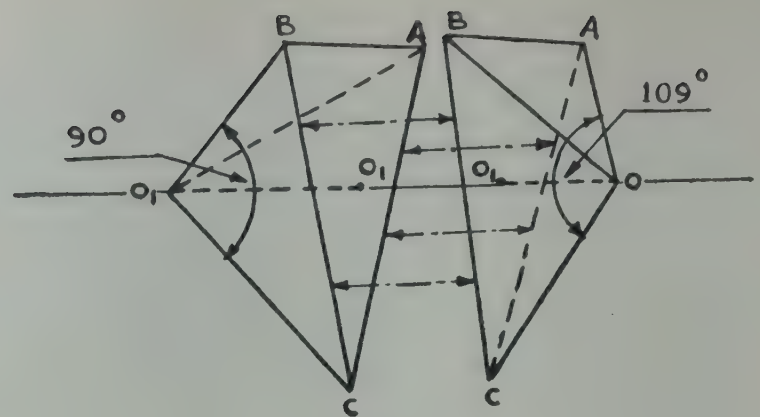


Fig. 5(p)

O is the centre of tetrahedron. AO, BO, DO represent one three-directional tetrahedral coordinate in one direction in the configuration.

Component configuration in one direction.

$$\text{Area of surface OACD} = 2.3\sqrt{3}$$

$$\text{Vol. of WXZ or ABC} = 2\sqrt{3} \text{ and Vol. of}$$

$$\text{Cabd} = 4\sqrt{3}$$

Surface volume ratios of two sides at equilibrium:

$$\frac{\text{ABD}}{\text{OACD}} \text{ Vs } \frac{\text{YACD}}{\text{acd}} \text{ Or } \frac{2.3\sqrt{3}}{2\sqrt{3}} = \frac{4\sqrt{3}}{2.3\sqrt{3}}$$

$$\text{Eq. Constants} = \frac{2.3\sqrt{3}}{2} \cdot \frac{2.3\sqrt{3}}{4\sqrt{3}} = \frac{3^2}{2}$$

which dimensionally is L^4/T^2 .

Like the equilibrium configuration of the universal wave equilibrium cubical configuration is made up of component configurations in one direction of the configuration as resultant of 3-directional tetrahedral coordinate from the centre acting in opposition to a three-directional rectangular coordinate from the boundary of the cube. The equilibrium space-time dimensional constant for this configurational relation works out to L^4/T^2 . The total configuration of the cube in different 2 such possibilities in opposite direction complete configuration of cube and the dimensional constant is $(L^4/T^2)^2$.

If should be noted that if the development would have retained perfect isotropy, in terms of coordinates of space/time, the configuration would have been that of universal wave generated. All the component configurations in that case were regular tetrahedral ones. In the case of the cube, however, the central tetrahedron is surrounded by two 3-directional rectangular coordinates. The equilibrium space-time constancy in relationship in the resulting component configuration is no longer L^4/T^4 in one direction. The configuration has been distorted to give space-time dimensional constancy as L^4/T^2 in one direction instead

of L^4/T^4 for universal configuration, resulting in developed an isotropy in the configuration of cube.

Constancy of Dimensional Relationships of Space-Time Coordinates in the Configuration of Octahedron

The configuration of octahedron which has been described before, is generated by two 3-directional rectangular coordinates acting in opposition through a common point of reference. From the surface volume ratio for the two equilateral triangular surfaces and the two volumes enclosed by 3-directional rectangular coordinates, the space-time dimensional constancy of equilibrium is L^2/T^2 as has been deduced in the following.

Regular octahedral positions are generated from three out of four tetrahedral positions vibrating in opposite phases such that the distance between mid points of the triangular faces in the opposite faces is the altitude of the tetrahedron in both phases. The tetrahedron can also be considered to be generated by two 3-directional rectangular coordinates acting in opposition through a common point of reference of the coordinates as shown below in Figs. 5(q) and 5(r)

Magnitudes of important dimensions:

Centre of configuration to mid triangular face	2
Centre to corner positions	$2\sqrt{3}$
Side	$2\sqrt{2}\sqrt{3}$
Median of a triangular face	$3\sqrt{2}$
Area of one triangular face	$2.3\sqrt{3}$
Volume of one quadrant i.e. one triangular pyramid say $O_1 CBD$ or $O_1 dcb$ which is also same as volume enclosed by 3 directional rectangular coordinates to the three positions from reference point	$4\sqrt{3}$

Equilibrium is due to two triangular surfaces, BCD and bcd and 2 volumes of quadrants $O_1 BCD$ and $O_1 bcd$ acting in opposition, i.e. equilibrium of $2.2.3\sqrt{3}$ Vs $2.4\sqrt{3}$ or

$$\frac{2.2.3\sqrt{3}\sqrt{3}}{2.4\sqrt{3}} = \frac{3}{2} \text{ Eq. constant.}$$

Constancy of space time coordinates for equilibrium $= L^2/T^2$.

Although the six positions described by the coordinates apparently give the configuration of octahedron yet the description covers only two quadrants leaving as if the other quadrants are out of consideration. This gives description of component configuration in one

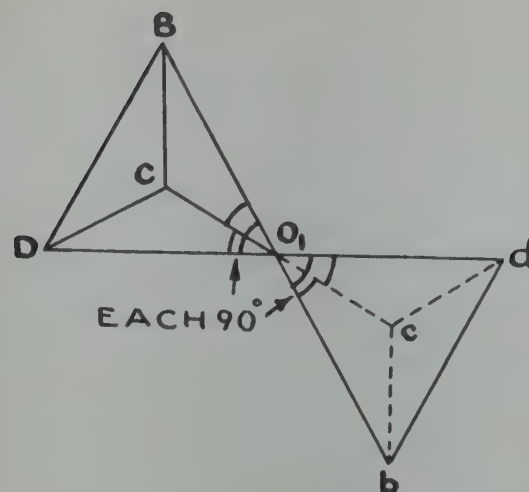


Fig. 5(q)

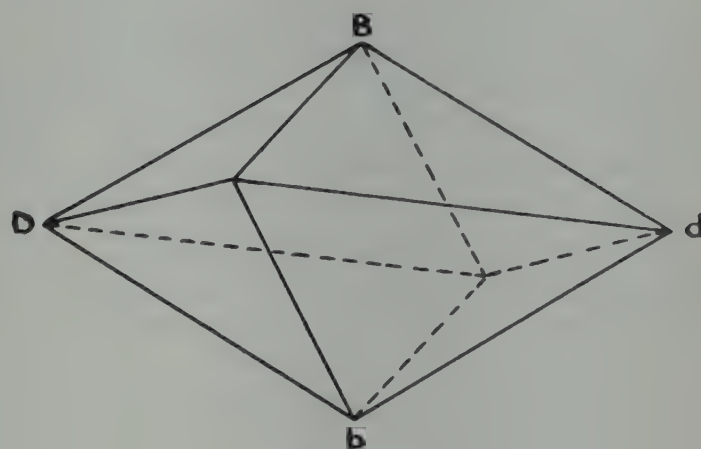


Fig. 5(r)

Complete configuration of octahedron.

direction of the configuration. The constancy of space-time dimensional relationship for this component configuration in one direction is L^2/T^2 , as compared to L^4/T^2 for cube and L^4/T^4 for universal configuration. If the whole configuration of octahedron in 4 directions would be considered, then the space time relationships for 4 directions of the octahedron would be $(L^2/T^2)^4$.

We can thus see that in the three configurations how they are generated by action and reaction of different coordinates in different manner. In case of perfect isotropic configuration in one direction the space-time relationship is L^4/T^4 . In the configuration of cube, isotropy is lost and the configuration has equilibrium constancy of space-time coordinates as L^4/T^2 . In the case of octahedron further distortion and deficiency in isotropy creeps in as is reflected in space time dimensional constancy for the configuration as L^2/T^2 .

If one would consider the reasons for the difference in the space time relationships for different configur-

ations, one would find the cause lying in the degree of isotropy or in the nature of coordinates which are in opposition generating the equilibrium configuration. No finite configuration is complete in equilibrium which is not constituted of component configurations generated by opposing coordinates. While making an analysis of an equilibrium configuration as a whole, therefore, it is absolutely essential to know the opposing coordinates. By merely knowing one coordinate to decipher complete significance of an equilibrium configuration generated by opposing dimensions and coordinates is not possible because that can at most reveal only a part of the whole. Because the other parts of the configuration contributed by the opposite coordinates and dimensions will not be revealed and realised.

It is thus important that to understand any manifestation or any phenomenon in the universe, in order to get the truth one must have got to know the coordinates in opposition involved, their directional probabilities and also the nature of the opposing dimensions. If that would not be done no phenomenon would be understood in its real perspective.

The configuration of regular tetrahedron is the most isotropic one. All other configurations are less isotropic. The degree of isotropy of configuration depends on the opposing coordinates of positions relative to reference points (i.e. it depends on how one looks at it; from what reference point with what coordinates and what are the opposite dimensions). All informations or data for knowing any configurations in the Universe lie in the configuration of the regular tetrahedron itself which is most isotropic.

It should be clear from the discussion in the above that any configuration in perception (or in reality) is actually an equilibrium of two or more component configurations acting and reacting in opposite phases. All configurations on analysis should be resolvable into simpler component configurations. Tetrahedron, though the simplest and most elementary is the perfect isotropic configuration. The synthesis of more complicated configurations structures like octahedron, cube etc. are configurations which are progressively less isotropic. In this outlook spherical surface is the least isotropic configuration in relation to positions.

The component configurations while acting and reacting in opposition generating the equilibrium configuration, would, for maintenance of equilibrium configuration, have equilibrium space time relationship constancies for a particular equilibrium configuration. Just as the equilibrium configurations which were related to equilibrium constants in equations

A_1 , A_2 , A_3 and A_4 deduced before all equilibrium configurations if analysed properly in proper perspective, would similarly yield equilibrium constants in terms of relationships of space and time. Tables, 1, 2, 3, 4, 5, 6, 7, etc. all show that when simplest and most isotropic configuration of tetrahedral development of space takes place, the magnitude of increase of size of configuration varies in terms of units of a chosen dimension in the configuration of tetrahedron such as distance from centre to faces, centre to mid side, evolved side, median, altitude etc. and all have different space time dimensional constants.

Effect of Relative Variation of Reference Point of Coordinates with Positions in Space on Space-Time Dimensional Constancies of Coordinates

In Table 4, we have shown the various dimensional relationships in a tetrahedral unit configuration of regular tetrahedron. We have shown that the space-time dimensional constancies with configuration of regular tetrahedron in terms of ratios of the various dimensions in the configuration which maintains purity (isotropy) of the configuration. If these dimensional relationships are not maintained constant, the isotropy (nature of the configuration) will change. For example, for a regular tetrahedron, whatever the magnitude of size of the regular tetrahedron, the side to altitude ratio will always in relative magnitudes be $\sqrt{3}/\sqrt{2}$. Dimensionally, it is L/T. If the altitude varies while the triangular base remains constant, then the side to altituder atio will also change. Consequently, the dimensional relationship L/T for tetrahedron (which will no longer be regular) will also change. Every coordinate as well as every configuration, for that matter, has certain constant dimensional relationship in its constitution. If the reference coordinates to positions change from one type to another or the positions themselves undergo change in relation to each other, the space-time dimensional relationship also changes. In the following discussion, in the illustrative cases we have only taken 3 kinds of 3-directional coordinates, viz. 60° , 90° and 109° , from a reference point to 3 positions. Only simple mode of variation of the reference point vis-a-vis the positions have been discussed. In the first case (Table 16) the reference positions B, D, C form equilateral triangular base of the tetrahedron with O' mid point of the face and AO' the altitude. The positions B, C and D retain constancy. The reference point will vary along AO'. In the second case, which is illustrated in Table 17, the altitude or height AO' has been maintained constant such that depending on the coordinates to positions employed at A (varying from 60° to 109°)

positions of B, C and D will also change in the same plane and hence the triangular area to suit the different coordinates. In Tables 16 and 17, the results of these various variations in terms of magnitudes of dimensions have been tabulated.

In Table 16 the positions B, C and D form the equilateral triangular face of regular tetrahedron ABCD and maintain constancy of position in the three cases (a), (b) and (c). In (c) the reference point is A, i.e. one position of the tetrahedron itself is taken as one reference point from which the coordinates towards B, C and D are 3-directional 60° coordinates. O' , the mid position of triangular face BCD in all the three cases is also the equilibrium centre position between the three positions BCD. In (b), O_1 is the mid position of the altitude AO' of the configuration. From O_1 as reference the three coordinates O_1B , O_1D , O_1C are rectangular (90°) three directional coordinates. In (a) the coordinates to three positions BCD are from the reference point O, the centre of the tetrahedron. The coordinate in this case is three directional tetrahedral (109°). AO' in (c) is the altitude; in terms of magnitude of units of distance this is 4. O_1O' in (b) is 2 in terms of units of distance and the magnitude of OO' in (a) is one unit of distance. In Table 16 the magnitudes of various dimensions in terms of relative magnitudes of dimensions in regular tetrahedral unit configuration have been employed. It may be seen that in the three cases the side by altitude is dimensionally presented as L^2 for tetrahedral coordinate. For rectangular coordinate it is L and for the 60° coordinate it is L/T . The relative space time magnitudes in between the positions remaining constant the variation of reference

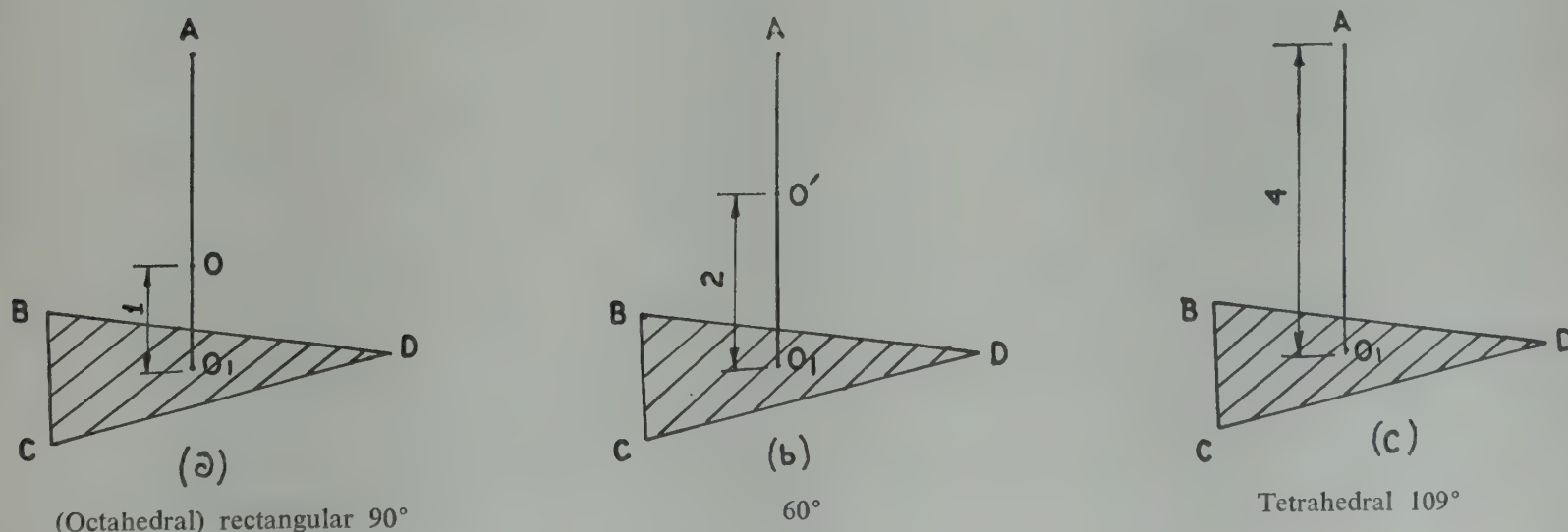
point with respect to the position develops different coordinates and also simultaneously develops different nature and magnitudes of dimensional significance.

In Table 17, in the figures a, b, c, are shown the reference position A and the mid point of the triangular surface of three positions which retain constancy of magnitude of distance in the three figures. In figure c, ABCD has been assumed to be regular tetrahedron of which the altitude AO' is 4 units of distance. In figure (b) AO' retains 4 units of distance, but $B'C'D'$ occupies positions such that the coordinates from A towards the positions are three directional 90° . In the same way in figure (a) AO' retains 4 units of distance. But $B''C''D''$ occupies position such that the three directional coordinates from A towards the three positions $B''C''D''$ are 109° tetrahedral.

It may be observed from the tables that in this case also the space time relationship of the coordinates towards the positions in terms of side/altitude ratio is L^2 for three directional tetrahedral, L for three directional 90° rectangular and L/T for three-directional 60° coordinates, towards the positions. In the table space time dimensional relationship of the three kinds of coordinates in terms of ratio of other dimensions of the configuration has been listed. A significant observation can be made from the list about the space time relationship for the coordinates when expressed in terms of ratio of altitude and median of base triangle to side of the triangular pyramid. For three directional tetrahedral coordinate it is T, for three directional rectangular coordinate it is L/T , and for three directional 60° coordinate it is L/T^2 .

TABLE 16

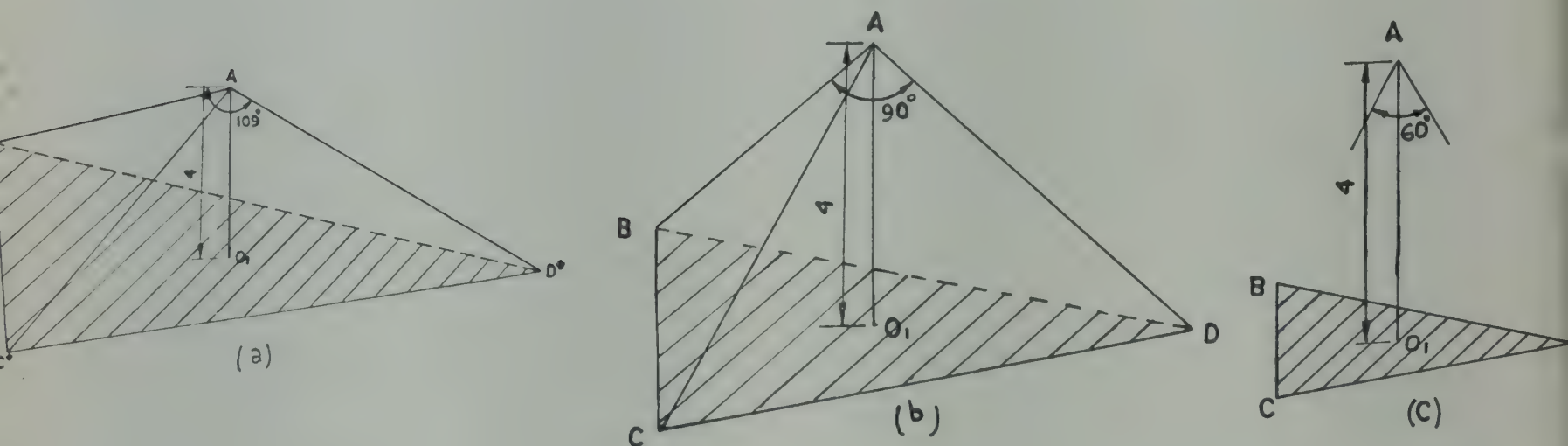
Relationships in coordinates of three positions having constant surface area between the three:



	109°	90°	60°	Side by altitude			
Height or altitude O	1	2	4	dimensional pre-			
Side of triangular				sensation	L^2	L	L/T
pyramid $2\sqrt{2}$	3	$2\sqrt{3}$	$2\sqrt{2}\sqrt{3}$	Mid point of face to	$\frac{2\sqrt{2}}{1}T^3$	$\frac{2\sqrt{2}}{2}T$	$\frac{2\sqrt{2}}{4}1/T$
Side by altitude ratio	3	$\sqrt{3}$	$\sqrt{3}/\sqrt{2}$	corner altitude			

TABLE 17

Coordinates of three positions with constant altitude and varying magnitudes of base triangular area:



<i>Plane infinite area</i>	<i>Tetrahedral</i> 109°	<i>(Octahedral)</i> <i>rectangular</i> 90°	60°
Height or altitude 4	4	4	4
Side of triangular base	$4.2\sqrt{2}\sqrt{3}$ T^7L	$4\sqrt{2}\sqrt{3}$ T^5L	$2\sqrt{2}\sqrt{3}$ T^3L
Side of triangular Pyramid	3.4 T^4L^2	$4\sqrt{3}$ T^4L	$2\sqrt{2}\sqrt{3}$ T^3L
Median of triangular base (Radius)	$4.3\sqrt{2}$ [4. (2√2)]	$2.3\sqrt{2}$ [2(√2)]	$3\sqrt{2}$ [2√2]
Area of triangular base	—	—	$2.3\sqrt{3}$
Side of triangular pyramid altitude	L^2	L	L/T
<i>Altitude</i> Side of triangular base	$L/T^3/L$	$1/TL$	$\frac{\sqrt{2}}{\sqrt{3}} = T/L$

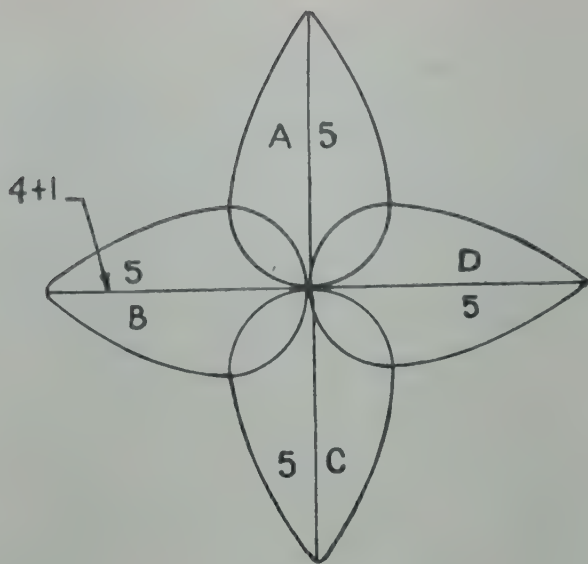


Fig. 6(b)

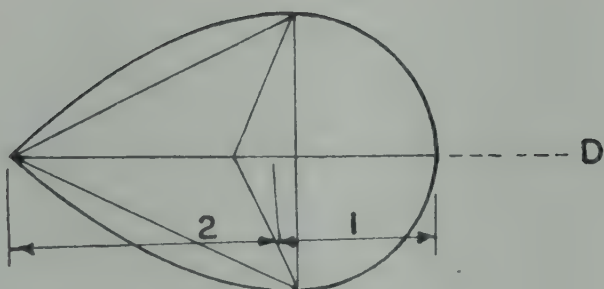


Fig. 6(c)



FIG. 6d

and the universal wave would be described then the component configuration would take the form of egg-shaped curve-surface configuration in one direction as shown in Fig. 6(a) and taking 4 directions in the configuration of universal wave it would take the configuration of 6b. The reason for egg-shaped or elliptical surface of development is due to the equilibrium configuration established by the 60° Vrs. 109° coordinates.

Similarly the configuration of cube in one direction would look like 6(c) in one direction and 6(d) in opposite phases in continuous development of positions. These configurations 6(c), and 6(d) are somewhat similar to 6(a) and 6(b); but in the former case the component configuration in one direction is more towards

spherical since the equilibrium configuration is established by the action and reaction of 90° and 109° three directional coordinates as against 60° and 109° 3-directional coordinates in the case of universal wave. In the universal wave the radial development takes place from 1 to 5. In the case of component configuration in one direction of the cube the radial development takes place from 1 to 3. Taking the configuration of octahedron in one direction the configuration indicating the continuous development would be like the one shown in Fig. 6(e.)

It is not intended to go into details of further development of configuration and their application to the mechanism of generation of wave due to action and reaction of various kinds of coordinates. But it suffices to say, from what has been discussed in the above, that since different geometrical configurations are equilibrium of different types of opposing coordinates of positions, the configuration of waves would also depend on the nature of the opposing coordinates which would generate the equilibrium configurations of the wave. If a tetrahedral coordinate of positions would generate equilibrium wave reacting with 60° coordinate the wave structure would be different from another wave which would be generated by opposite coordinates of positions like 90° and 60° and so on. The nature of the reacting coordinates will be the decisive factor for the surface contour of the wave.

Problem of Parity in Wave Mechanics and K-meson Decay

In the background of analysis and deductions (the results of discussions) in the previous sections in respect of generation of equilibrium configuration of positions in space by opposite coordinates of positions, it would be of special significance and interest to compare those

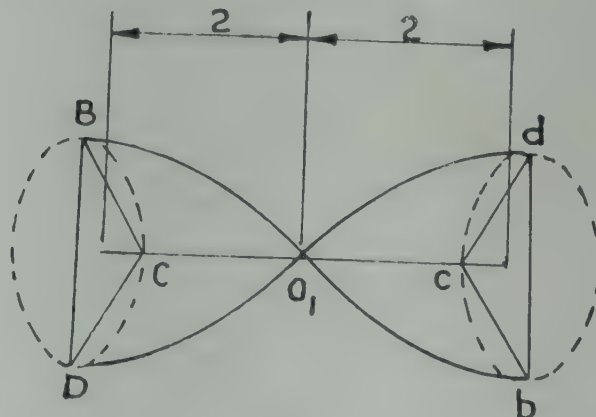


Fig. 6(e)

findings with the phenomenon observed during decay of K-meson in which, at different instants, degradation of particles are found to occur which do not seem to obey the principle of parity conservation in wave mechanics. The results and findings from the present theory can also be seen against the principle of parity which forms the very basis of wave mechanics on the one hand and observed results of K-meson decay on the other. In the following discussion an attempt has been made to explain these aspects in terms of space time coordinates of position in equilibrium configurations of positions in space. For full explanation reference should also be made to section entitled "Evolution of numerals and concept of magnitudes of digits in the light of space time coordinates of position" in the companion volume.

In the systems of coordinates in the equilibrium configurations of octahedron and cube which involve 3 directional coordinates, the probability of simultaneous appearance of positions in opposite phases generates the equilibrium configuration of either cube or octahedron, depending on the nature of the coordinates and mode of their functioning in establishing the equilibrium configuration of positions in opposite phases. In octahedron 3 positions in one phase act in opposition to 3 positions in opposite phase through a central position in the configuration through three directional rectangular system of coordinates. In the equilibrium configuration of cube, however, the 4 positions of original tetrahedron in one phase are in equilibrium with 4 positions in the opposite phase. The simultaneous presence of 8 positions in both phases generates the equilibrium configuration of cube.

For the equilibrium configuration, simultaneous presence of the positions in space in opposite phases is essential. This would mean that the frequency of occurrence of the positions in one phase and in the opposite phase should be such as to give simultaneity of occurrence of the positions in both phases. In other words, frequency of occurrence should be very high. If, however, the frequency of their occurrence in the two opposite phases is less, the configuration would be one of positions of three or four in one phase at one time followed by position of three or four in opposite phase and this will go on repeating with time for octahedron or cube respectively. In the case of cube 4 positions of tetrahedron in one phase would be observed distinct in one phase at one instant followed by occurrence of another 4 positions in opposite phase at another instant (i.e. after an interval of time). In case of octahedron 3 positions of one triangular face of tetra-

hedron would be observed as distinct in one phase at one instant followed by occurrence of another 3 similar but opposite positions in opposite phase at another instant. These are shown in Figs. 7 and 8.

The significant point here is that the overall equilibrium configuration in both cases requires simultaneous presence of the positions in the opposite phases to give the impression of the positions in the opposite phases complete equilibrium configuration. But the equilibrium configurations would depend on the alignment

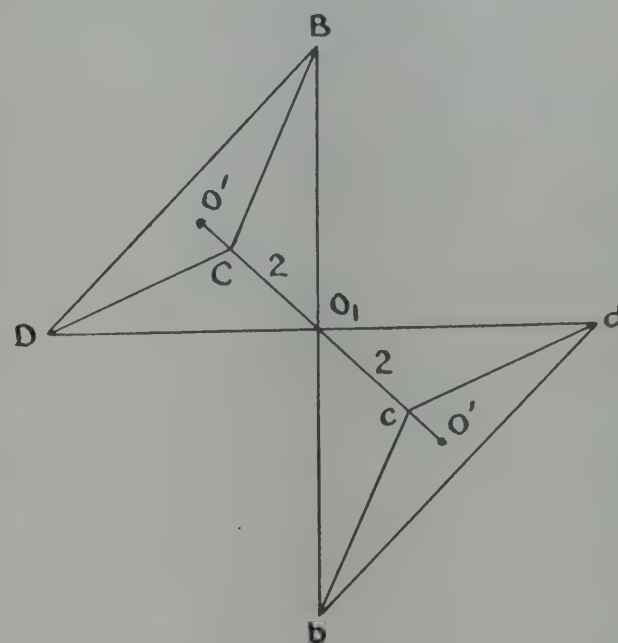


Fig. 7(a)

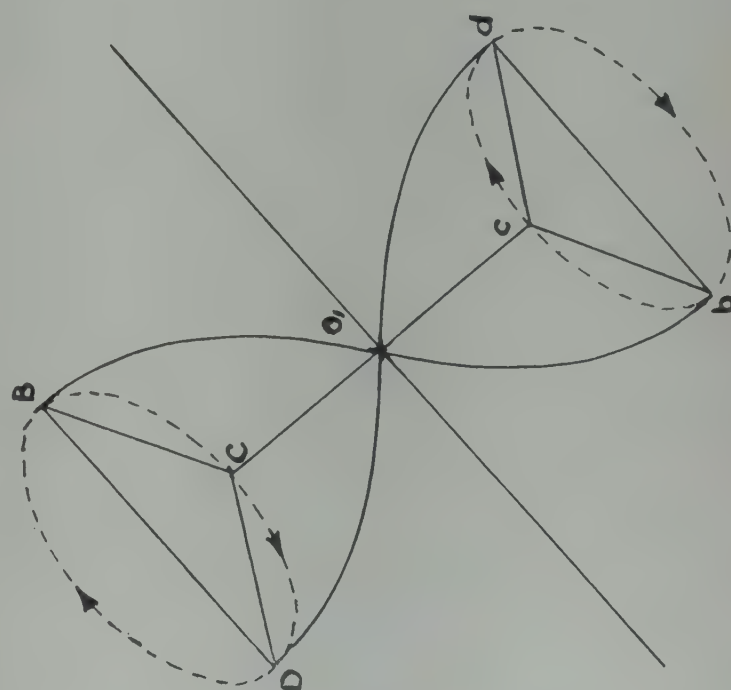


Fig. 7(b)

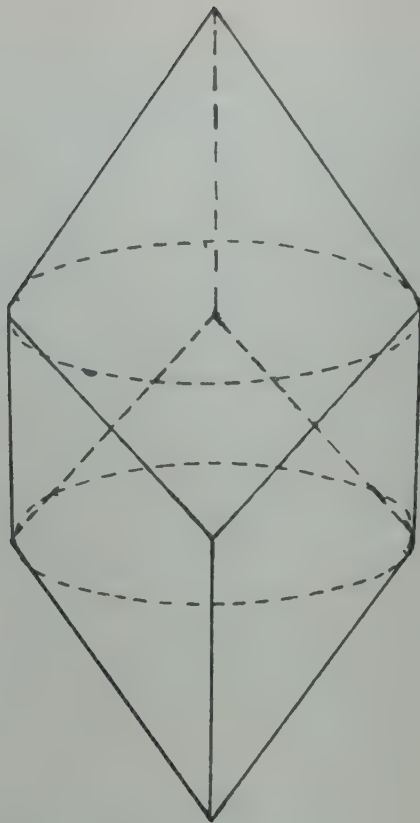


Fig. 8(a)

of the coordinates of the positions for cube as well as for octahedron. The alignment of coordinates for three with respect to one would require two rectangular coordinates through two positions in opposite phases for cube; whereas in case of octahedron it would require the rectangular coordinates from three positions in opposite phases through one common position. The nature of functioning of the coordinates in these two cases determines the nature of configuration also, but in the equilibrium picture as a whole in both the configurations one would observe that in the same configuration one set of positions are in one phase having one set of properties and simultaneous presence of another set of positions in the opposite phase having opposite set of properties. Therefore for a system of coordinates of positions generating an equilibrium configuration, the latter must be constituted of and associated with it in-built coordinates of positions in opposite phases. This is inherent in the evolution of configuration of positions in space. This should be true in case of configuration of wave structure also.

It is thus obvious that if a configuration of positions like a cube or an octahedron in space, will move as a whole the configuration also moves in which the positions in opposite phases having the opposite characteristics associate and simultaneously move together. Whatever be the direction, it would give the impression that one set of positions in one phase is the mirror image of other set simultaneously moving in the same direction [Figs. 7(a), 7(b), 8(a) and 8(b)]. This would however be the picture when frequency of occurrence of the positions is very high i.e. their occurrence is simultaneous. If, however, the interval between the occurrence in the opposite phases is high i.e. the frequency of occurrence is low, the equilibrium configuration of simultaneity breaks down into component coordinates of positions in opposite phases which would be observed as distinct and opposite at different intervals of time.

These background mechanism and various resulting configurations of positions and the nature of their coordinates should be borne in mind while making any analysis of observed results in phenomena involving positions of matter to energy transformation and vice versa in space.

Cosmic rays in general and mesons in particular, it is known, when are directed during their decay towards the surface of the earth, the shower takes the form of a cone. The picture is, if the starting point would have been the apex of the cone, the end points of positions in the generated configuration at the end of decay would form the base of the cone. This is the

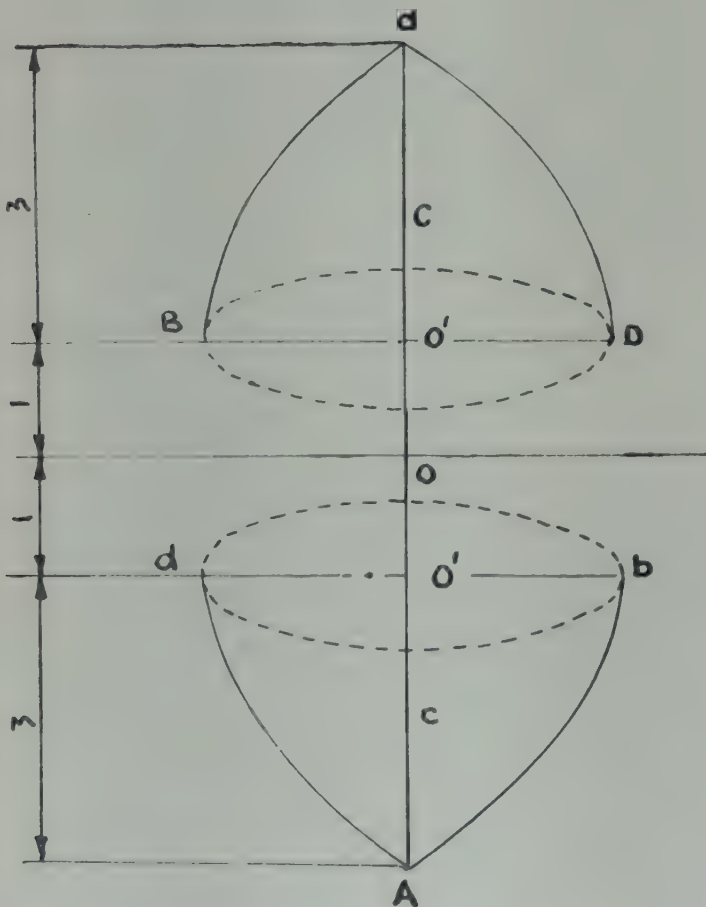


Fig. 8(b)

picture of action of decay of meson positions in one phase in one direction. Then what about the reaction of the media in which the decay of meson is taking place? The reaction must take the form of opposite phase. It thus raises the question in what manner decay of mesons is occurring and in what media and at what rate? It is in real vacuum or in space? The latter in the present theory is energy itself. Is it taking place in ordinary atmosphere or is it in medium of positions of reaction products created during the action of decay itself? If the decay would take place in real vacuum the reaction in the opposite phase would have been due to the property of real vacuum and in the present theory this is nothing or imaginary. If, however, the decay takes place in a medium of space or energy the reaction in the opposite phase will be due to created positions in space due to action of decay of mesons. For the sake of illustration, if the configuration of cone in the process of decay would be assumed as a Tetrahedron, one position of it is prior (previous) and 3 subsequent positions forming the subsequent equilibrium triangular base at the end of decay. The reaction by the decayed positions in space could generate another opposite set of 4 positions in space in which the meson's decay takes place generating in equilibrium 2 sets of opposite positions having opposite characteristics. Thus if the positions in the first phase have one spin or orbital motion, then the positions in the opposite phase will have opposites; they will be mirror image of each other. Therefore, when the mesons undergo decay, the background medium provide positions as reaction to action of decay. The action of positions undergoing decay and the reaction of the positions in the medium in which the decay is occurring, react opposite and form equilibrium configuration in which the positions of mirror image can simultaneously occur. If such configuration of two sets of positions undergo translatory motion, the two sets of positions together can undergo simultaneous motion.

If, however, there would be time lag between the action and reaction of the opposite sets of positions i.e. between occurrence of two sets of positions, two distinct opposite phenomena would be observed at different intervals of time.

Resultant or equilibrium configuration in this mechanism is due to opposite component coordinates (not same) which also should be true for configuration of equilibrium wave also. The two components generating the wave must be opposites, not same or identical, be it in their properties as dimensions (as matter and energy or particle and space) or direction of coordinate

or spins and so on and so forth. So called particles generating an equilibrium wave are not identical. If one is matter particle which should occupy a position in space only, its opposite to complete the wave structure, should have property which should be opposite of positions. In other words the latter should be space intensive i.e. energy intensive. Energy and matter are opposites and they two together make the concept of configuration of wave. If neutrino is matter intensive, anti-neutrino should be energy intensive. If the occurrence of positions due to neutrinos and anti-neutrinos is instantaneous, wave configuration could be complete, if however their occurrence would have a time lag these two would be observed as distinct opposites.

To clarify this point in the configuration of the universal wave, the boundary position like 'X' has 3 directions to 3 matter positions as B, C and D which form the triangular face of the central tetrahedron. These 3 positions are matter positions although relative to 'X', B, C and D positions are more energy intensive. Similarly, the mid position of the triangle BCD in space has 3 coordinates towards the 3 positions B, C and D although the mid position 'O₁' of triangular face is a position in space but it is more energy intensive and has 3 coordinates. Whereas the position 'X' was a position equivalent to a particle of infinite matter intensity i.e. all mass. The centre of the central tetrahedron O is also an imaginary position in space where the energy intensity is infinity i.e. all energy and it has 4 directional coordinates towards 4 positions in space A, B, C and D of matter significance. A position, therefore, can differ in its nature of coordinates and also of matter and energy significance. The centre has 4 directional tetrahedral coordinates. A position in the boundary like 'X' has 60° coordinates and is of a particulate nature whereas the positions B, C and D belonging to the central tetrahedron are not particulate but the positions possessing half significance of both.

The parity of positions of particle in wave mechanical function does not contain an opposite associated with it to give it an equilibrium configuration of the wave. What is intended to convey here is that the basic assumptions made in defining the wave mechanical structure or *configuration of wave* contains only parity of positions in one direction, with one directional aspect only and with positions having positive and negative or pro and anti aspects together due to opposites. The concept of the wave as equilibrium of two opposite parities due to opposites, it appears, is not involved in the mechanism of wave functions. The basic assumptions of the quantum theory thus assumes these factors

like particle which is *position intensive* but it does not take into account *that aspect of position in the wave which is space intensive* which are required for generation of equilibrium configuration with simultaneous presence of opposites making equilibrium configuration complete.

That this contention has some substance in it is also borne out from the dimensional analysis of Planck's constant. Planck's constant has the dimension of $E \times T$ as erg second. Any equilibrium configuration however must be made up of space as well as time; association of energy with only one dimension e.g. time to generate an equilibrium configuration without the association of dimension 'L' is incomplete. The other aspect is that energy also, in the equilibrium wave, must be associated for equilibrium existence with its counterpart matter significance of matter dimension.

Therefore, the dimensional realisation of Planck's constant is only half relevant. The constant, as it is as erg second or dimensionally as ET , must be associated with other half, its opposites, which is dimensionally ML . The matter being opposite of ET should be denominator with ET as numerator. Thus the real dimensional association of the Planck's constant would be ET/ML . This conclusion is in conformity with deductions in the light of the present theory from dimensional analysis of fundamental equation in modern statistics from which it was shown that dimensionally the degeneracy parameter essentially is ET/ML .*

The description of the universal wave involves 4 dimensions, energy, matter, space and time; of which energy is the fundamental dimension which causes Universal matter manifestation with subsequent association of the derived dimensions matter with space, time and variability in space configuration. The dimensional association of equilibrium constant with the universal spherical wave was shown as $ET/ML = \text{constant}$. It was also shown that any equilibrium concept retaining self-sufficient existence must comprise of 4 dimensions like energy—matter—space—time in which two pairs, each of two opposites establish the equilibrium which can be symbolically presented as $+/- = -/+$. In the case of energy matter equilibrium in the universal spherical wave, the variation of the magnitudes of these dimensions permits the variation of the resultant magnitudes of the equilibrium constant from 1 to $+$ or $-$ infinity.

These aspects of generation of magnitudes of equilibrium configurations due to opposing coordinates relative to reference positions having opposite dimensional significance will further be discussed in another article, where it will be shown that the magnitudes of space-time coordinates while in opposition generate equilibrium configurations of numerical magnitudes of numbers as digits also.

* Chakravorty, K. R., Energy Field of the Universe and Atom, Part II, The Theory of Universal Spherical Wave and Modern Science, Technol 2(4), 1965.

Evolution of Decimal and Octate System of Numbers and their Magnitudes as Configuration of Space-Time Coordinates in the Light of the Theory of Universal Wave

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Numbers are equilibrium magnitudes of opposite concepts as digits between opposite limits of magnitudes as centre and boundary in one direction of space-time co-ordinates in the configuration of Universal Wave. Evolution of numbers as decimal system and octate system has been explained in the light of the configuration of universal wave. The concept of digits in the light of universal wave has been identified with the concept of numerals in Sankhyya Science. Significance of magnitudes of Zero and Infinity as well as Mathematics of Zero and Infinity has been explained in the light of the configuration of universal wave. Significance of the terms identical, different and opposite as well as magnitude of difference between two has also been explained.

EVOLUTION OF SCIENCE OF NUMBERS

Evolution of Numerals and Concept of Magnitudes of Digits in the light of the Theory of Energy Field of the Universe and Atom

A brief description is given below, for the sake of recapitulation and ready reference, of the standard configuration of the universal wave. For detailed consideration, reference may be made to the Introduction to Understanding of the Theory of Universal Spherical Wave (Technol., Vol. 3, No. 2, 1966) and "Energy Field of the Universe and Atom" (Part II).

The spherical wave is a configuration of concept of self-sufficient manifestation capable of independent equilibrium existence. The manifestation exists in equilibrium owing to factors which are within it; for explanation of any event within it, no reference to anything outside is required. The universal wave requires a fundamental dimension to cause its manifestation. The evolution of the wave starts through a point of position having nil magnitude of configuration, where the fundamental dimension exists in its infinitely pure state. This point becomes the centre i.e. origin of the spherical wave.

It is necessary to understand the configuration of the standard universal spherical wave, relative to energy-matter universal manifestation, taking into account the various dimensions involved and the variations in their magnitudes in the wave between the central point of position and the boundary of the evolutionary wave. Energy and matter are opposite dimensions which constitute the wave in association with space and time coordinates to give the configuration of the wave. Energy is fundamental which causes evolution and matter is derived dimension in the configuration of the caused evolution. Space is the containing dimension of fundamental energy and time is containing dimension of derived matter dimension. Action of space is radial; reaction of time is orbital in space time configuration. The central point of position is the one which assumes the property of the fundamental, energy of infinite intensity (which in reality means energy in its infinitely pure state of existence) and the associated positions (forming tetrahedral concept) in that state are imaginary and may be assumed to be condensed into one of nil magnitude of size of configuration with nil intensity of matter associated with the positions, i.e. although the points of position retain imaginary tetrahedral configuration, with purest energy at centre, the 4 posi-

tions for matter contain nil matter. The first association of matter from their nil possession at the centre would be the first stage of the evolution at which matter association starts with least finite magnitude of configuration. The 4 evolved positions A, B, C and D from the centre, with generation of space by energy, will describe varying orbital paths, one after another, during evolution in stages till the equality equilibrium spherical surface locus of positions would be generated. In this evolution, two aspects are involved: (i) the stages or states and (ii) the intervals between two adjacent states. The first stage is the central state of positions (with nil matter) followed by second, third, fourth and the fifth stage which is the *equality equilibrium spherical surface* of the tetrahedral evolutionary wave. In these, there are four intervals between the first stage and the fifth stage. Beyond the fifth stage of equality equilibrium towards the boundary, there are again four stages viz. 6th, 7th, 8th and 9th. Beyond the 9th state, which signifies the highest finite evolutionary wave, at the next state, which is the boundary of the present wave, the magnitude of the fundamental would fall to nil and the derived dimension would increase in its intensity infinitely assuming a position of point concept of nil magnitude of configuration for the next evolution (relative to which the other dimensions of the present finite evolution would be irrelevant). For example at the boundary, associated energy intensity or space intensity would be nil and time intensity of infinite magnitude with nil magnitude of size. The derived dimension of the present evolution would at that state be converted into the fundamental dimension for the next evolution. The 10th state would be the theoretical conclusion or end of the present evolution and become the cause for the commencement of the next evolution.

Let us take the configuration of the spherical wave in Figs. 1(a) and 1(c); in one direction, the radial distance of the wave will be between the centroid and any one of the positions WXYZ. Let us take for consideration direction OX, which is the radius of the finally evolved spherical wave. Now we require some units for measurement of distance in the configuration. Let us assume the least distance from the centre to the mid-point of the plane of the triangular faces of the central tetrahedron to be one unit of radial space. In terms of this unit the entire spherical wave can be evaluated. Thus, the distance from the centroid to the apex positions in a regular tetrahedron would be 3 units. When two tetrahedrons are placed face to face, the distance between their centroids is 2 units and distance between two apex position is 8 units. If 4 tetrahedrons are placed against

4 faces of the central tetrahedron, as in Fig. 1(a) of the configuration of the spherical wave, the distance from the position of the centroid to the apex positions at the boundary viz. WXYZ would be 5 units. The diameter of the spherical wave would be 10 units, in which it may be noted that, including the centre, which is one state, the diameter will have two opposite positions at the boundary. Thus the 10 unit distances making the diameter has 11 limiting states including the state at the centre.

The above is the tetrahedral configuration of the generated spherical wave which has been developed up to the boundary. Now the question is: what were the relative states of the boundary, equality equilibrium and the centre at various states of evolution from the state when the configuration was of nil magnitude, i.e. energy was of infinite magnitude and matter nil?

Configuration of the Fundamental Dimension in its abstract state of existence

A point of great significance in respect of the fundamental dimension lies in its imaginary nature of configuration in its abstract state of existence. In its abstract state of existence it possesses infinite intensity. In this state, the fundamental does not associate with any other dimension. Thus in this abstract state it is in an infinitely pure state of existence. In the finite manifestation, however, from the previous state, the fundamental must start to assume a tetrahedral configuration of positions by associating least finite magnitudes of derived dimension in the configuration. Thus it may be construed that in its abstract state of existence also, the fundamental has tetrahedral configuration, which, in that state, is only imaginary and where none of the 4 positions is associated in any way with any other dimension. The configuration of the fundamental dimension is one of imaginary regular tetrahedral concept of nil magnitude (i.e. infinitely small magnitude of size); the centre of which is contained by infinitely pure fundamental dimension and the 4 positions of which contain nothing; from that state when the imaginary vacant positions of the configuration associate with derived dimension, finite evolution starts and becomes the universal manifestation by progressively increasing in magnitude of size of configuration till the evolution in the form of spherical wave comes to an end at an imaginary boundary of the wave, where fundamental falls to nil magnitude in intensity or purity and the derived assumes infinite magnitude.

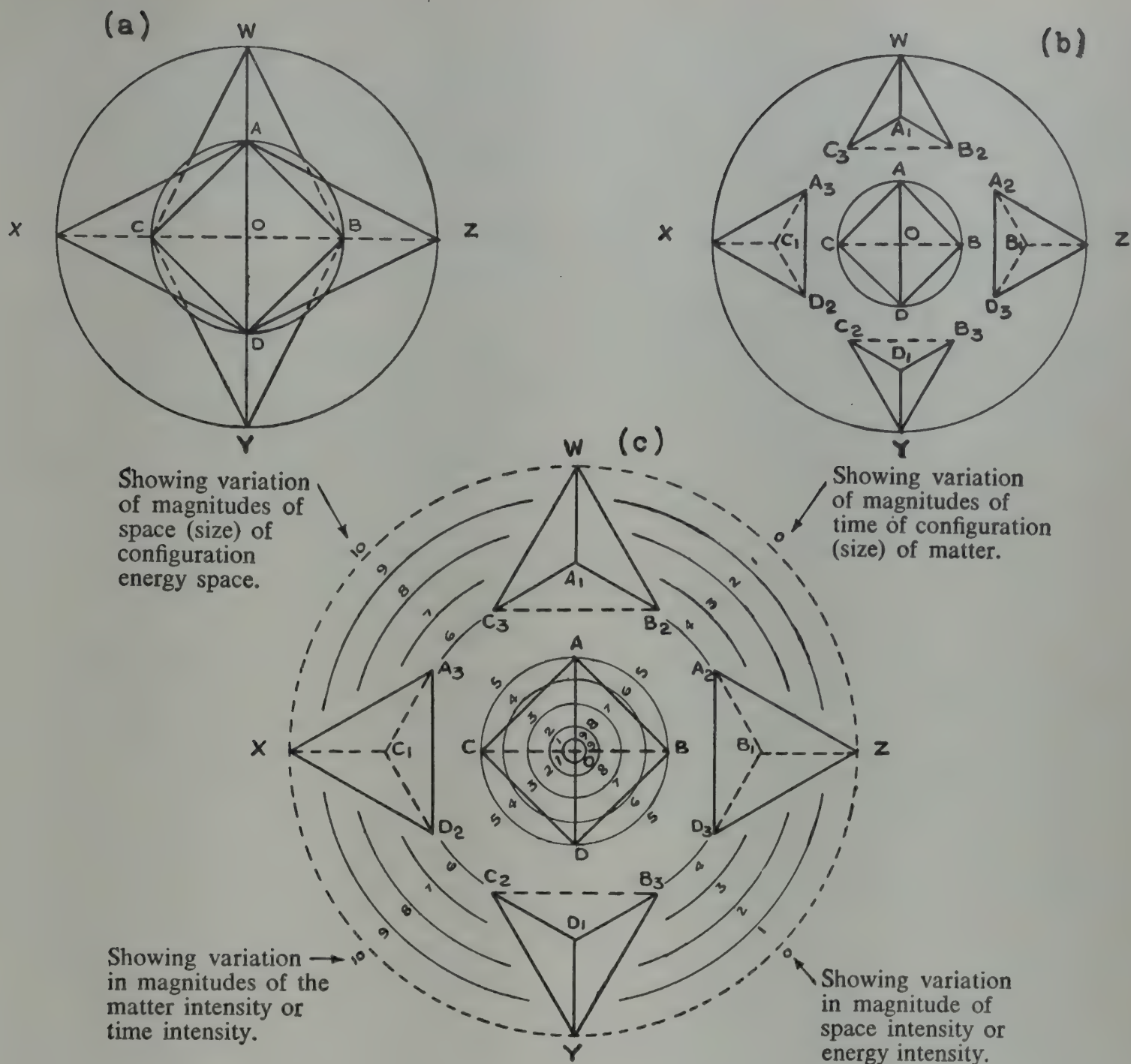


Fig. 1

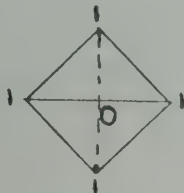
Fig. 1(a) represents a central tetrahedron ABCD together with four tetrahedrons placed face to face at the four triangular faces of the central tetrahedron. The central tetrahedron represents the homogeneous phase where the fundamental and derived dimensions exist in one inseparable form. The four outer tetrahedrons, with the intervening empty space, constitute the heterogeneous field of the Universal Spherical Wave, between ABCD and the boundary Spherical Surface passing through the apex positions W, X, Y and Z of the four tetrahedrons.

In Fig. 1(b) the same configuration in Fig. 1(a) has been shown by separating the four outer tetrahedrons from the inner one.

In Fig. 1(c) the same Universal Spherical Wave is shown, for clearer understanding by incorporating the spherical surfaces in between the centre and the boundary, four in the homogeneous and four in the heterogeneous zones.

Evolution of Magnitudes of Numbers and the Concept of Decimal System of Numbers in Configuration

Before the first evolution was started from the centre, the centre had nil magnitude of configuration and nil magnitudes of associated derived matter dimension in the position of the configuration. After evolution at the first state, the first 4 derived matter positions would be generated and would be located at the least distance from the centre, (the centre occupying nil derived), and would have least intensity signified by the symbol 1. Configuration of the first state, with respect to matter or magnitude of configuration, would be the state of least magnitude of configuration, relating to matter as: 0, 1 and 2.



The first stage would be followed by increasing numerical sequence of states of magnitudes of configuration, retaining the trahedral concept of evolution. When the first evolved tetrahedron, between the 4 evolved positions, progresses further, increasing magnitudes of variability dimension will progressively develop but retaining isotropic character; the 4 positions will vary isotropically not only with respect to the centre but with respect to evolved positions as well.

In the configuration of finite universal wave, the variation of positions on the evolved surface, development in one direction of the spherical wave with respect to the centre is more amenable to comprehension than taking into account all the 4 tetrahedral directions simultaneously. In the former case, variation would be between 3 positions with respect to one. The variation in one direction could be conceived of only in 2 opposite directions of 3 with respect to one position (opposite spins and opposite radial directions). Applying numerical magnitudes for fundamental and derived which establish the equilibrium as was enunciated in the equation of equilibrium expressed symbolically as $+/-=-/+,$ the action and reaction of the three with respect to one would be:

1	2	3
3	2	1
boundary	equality equilibrium	centre

(This is presented following symbolic presentation of equilibrium.) This would be the second stage of evolution; the first was the state equilibrium of 1 with nil magnitude of derived or nil magnitude of configuration at the centre. Similarly, the next higher numerical magnitude of equilibrium configuration would be three as shown in the following:

1	2	3	4	5
5	4	3	2	1
Boundary	Equality equilibrium			Centre

It may be seen from the above that, in the first evolution, the centre had nil significance of the derived dimension and the 4 tetrahedral positions the significance of equality of derived dimension, having magnitude of 1 each. It had no conceivable boundary nor centre but it itself constituted the equilibrium boundary. In the second evolution, the least magnitude of 1 of the first evolution is increased in magnitude and generates an equilibrium magnitude of 2 and there are 3 states between the 2 states on either side of the equilibrium magnitude of 2. In the third evolution, the equality equilibrium magnitudes of 3 has each 2 states on either side of 3. Thus altogether there are 5 states.

Similarly, the equality equilibrium states for 4 and 5 are shown below:

1	2		3	4	5	6	7	—Equilibrium of 4	
7	6		5	4	3	2	1		
Boundary		Equality equilibrium				Centre			
1	2	3	4	5	6	7	8	9	—Equilibrium
9	8	7	6	5	4	3	2	1	of 5
boundary		equality equilibrium				centre			

It may be seen that in the equality equilibrium of 4, there are 7 finite or perceptible states between the least and the highest of 1 and 7 and in the equality equilibrium of 5, there are 9 finite or perceptible states between the least and the highest of 1 and 9. In the tetrahedral evolution, equality equilibrium up to 5 can only be considered. When it is fully developed up to the equilibrium of 5, there are 9 states but the evolution started in the first case with the least magnitude of the evolved equality of 1 and the centre point had nil magnitude of the derived. If the equilibrium of 5 is the limit of tetrahedral evolutionary wave, then the equilibrium of 5 would only be extended to 9 finite different states and no more.

If, however, this finite presentation would have boundary on either side, the total number of states

would be 11. In the configuration of the spherical wave, one boundary would be the central point of nil magnitude of configuration and the other the spherical boundary of infinite magnitude of derived dimension; both these are, however, beyond perception. At the various finite states in the equilibrium of 5, starting from the first stage up to the 9th, each state will constitute a combination of magnitudes of derived and fundamental whose total is ten but each in varying magnitude. In this evolution, if the derived matter will have to increase in its magnitude beyond 9, then the magnitude of fundamental will be reduced to less than 1 which would be nil. That state would thus become the location of the central point of infinite intensity of the present derived dimension relative to its magnitudes in the present wave and will be the starting point of the next evolution and which would be the end of the present finite evolution.

The above may be clarified by taking the example of the second and third series of elements in the periodic system of elements. There are 7 elements situated in 7 states whose distinctive properties can be realised. These lie between the two inert groups of element one before the first groups and another after the 7th group, total number of groups being 9. But the first and the 9th groups of inert elements have no distinctive properties as per normal chemical methods of perception. But the 7 groups of elements in between have distinctive properties. Thus, if we numerically designate the first inert gas with nil distinctive property and start with the first inert gas group and to arrive at 9th state, we pass through 7 perceptible groups of elements and designate 8 to the element in the 9th stage in the series which again is an inert gas. Thus the 8th element is actually a repetition of nil property of the first. The numbers which can be attributed to perceptible elements are 1 2 3 4 5 6 7.

Similarly, in the 5 equilibrium series, the central point will be with nil magnitude of the derived dimension (but infinite magnitude of fundamental) the spherical wave whose ultimate limit would be one which will start with the same property of infinite intensity of the derived for the next evolution and nil magnitude of the fundamental of the present evolution. In between, there are 9 states which are finite states from 1-9 and 5 is the equality equilibrium. It may be noted that, if the perceptible states from 1 to 9 are taken, then the number of intervals is 8. (The number of intervals in the previous case of octate was 6). In other words, these characteristics would be in the finite evolution in which everything is finite. Neither nil nor infinity are

involved in the combined magnitudes constituting the configuration. The decimal system, however, would apply to evolutionary wave starting with a point of nil magnitude size through finite magnitudes of fundamental and derived to the 10th state where magnitude of size is infinity and from where next evolution would start.

These evolutionary significances, which are associated with the designation of numerals as digits, as explained in the above, clearly establish that, in the tetrahedral evolutionary concept, there can be maximum 9 different finite digits of numerals indicating the finite states or stages of existence in the universal spherical wave interposed between a point, i.e. a central point of infinite fundamental (which is beyond conception) and infinite boundary surface with location of position of points of infinite derived (which again is a state of existence beyond conception). Symbolically, the first state can be represented by a dot on a plane of paper—the conventional point of position; the last state, which is a spherical surface locus of infinite magnitude and forms the boundary of one complete evolution in the present finite context of fundamental and derived dimensions, can be represented by a circle. *The concept of a point and the concept of circle symbolically in configuration are perfect opposites. One, which starts with point, must end up in a circle in evolution. Herein lies the essence or seeds of the decimal system of numerals.*

Magnitude of Numbers in terms of Three Directional Space Time Coordinates


It is common knowledge that progressive addition of *unit magnitudes* leads to magnitudes of final total. When one thinks about the generation of magnitude of an integrated whole made up of the cumulative results from progressive addition of individual units of magnitude, we are conventionally used to think that the *individual units*, during the process of their being added one after another in the direction of increase in succession of cumulative magnitudes towards final total magnitude, while they are being added in succession it is taken for granted that the units which are added one after another remain identical or at least similar in all respects. Even if the magnitude of the units during the process of addition towards generating the whole may progressively change in magnitude, during the process of addition itself it is assumed that, although magnitudes may be varying or may remain constant but their other *nature* remains constant or unchanged during the process. What is intended to explain in the

above may be clarified by the following example.

Let us attempt to measure a 4 metre distance, with a metre rod as unit of distance. Suppose one end of the rod is *marked red* and the other end *marked black*; If during the process of measurement we assume that the rod starts from the starting point with its red marked end, the first metre ends up with its black end. In the measurement of the second metre again, the rod can start measurement with its red end and again end up with its black at the end of second metre. This process may be repeated. In other words, during the process of measurement, the unit metre rod moves retaining identical or constancy of the directions of its red and black ends with the direction of measurement.

Method of measurement could also be performed using the metre rod starting from the starting point with red end of the rod and finishes one metre at the black end. To measure the second metre distance, the rod can start with black (instead of red in the first method) and end up with its red at the end of second metre. The third metre distance will start with red and end up in black at third metre distance. In measuring the fourth metre, the rod starts with black end and finishes measurement of 4 metre with its red end. The difference between the two methods of measurement are shown in the following:

Direction of Measurement:



Red-Black	Red-Black	Red-Black	Red-Black	First method
First metre	Second metre	Third metre	Fourth metre	
Red-Black	Black-Red	Red-Black	Black-Red	Second method

Apparently, whichever method we adopt for measurement of both integrated 4 metre total in terms of individual metres, both give the same total. But if one would go deeper into the mechanism of the two methods of measurement one would find very significant difference. In the conventional thinking, the measuring unit metre rod proceeds with sequence of red followed by black maintaining constancy in the direction of measurement at each unit metre of distance as in the first method. In the second method, red-black sequence varies; red-black in the first metre is followed by black-red in the second metre and red-black in third and black-red in the fourth metre. In the second method the sum of two metres is due to addition of two unit rods placed opposite in sequence in the direction of measurement. In the first method of measurement sum of two is due

to identicals. In the first case, the cumulative additions in the direction of measurement are due to repetition of the identical units. In both cases, the magnitude of the unit are constant. In one case it is repetition of identical mode of measurement by the reference unit rod and in the other case it is progressive addition of constant magnitudes of opposite units in succession make the sum total. From our day to day experience this may not convey much difference of significance because in any case the cumulative effect of two methods gives the integrated magnitude same in both cases and serves the same purpose. But the fundamental question arises as to whether in the mechanism of development of magnitude of size of configuration of space time coordinates will both the methods be valid or not. The significant point of difference in the two methods of measurement is that, in the first case, the black end always follows the red in every unit of distance measured, i.e. the red black order of the measuring rod remains constant at every unit distance. In the second case, for addition of two adjacent units the addition takes place between red black and black red or black red and red black: a pair of two units in opposite order. As mentioned before, this aspect may not seem to be of great consequence in our day to day experience but in the universal context, in which magnitude of size of space time configuration increases or decreases due to change in nature and magnitude of space time coordinates of positions, this aspect is bound to play a vital role.

In the article entitled “Geometry of space time configuration”, in section entitled “Problem of Parity and K-meson decay”, we have shown that in the basic assumptions of the Planck’s fundamental concept of quantum and also the fundamental concept of conservation of parity in wave mechanics the direction of measurement, half of the total concept is missing in both. Apparently, it seems that the principle of parity in the present case might be realised in the first method of measurement. But if the second mode of measurement would be employed then the parity, as defined, would not remain conserved. In the first method of measurement the order of red-black of the rod in the direction of measurement always remains the same. In the second method, *two opposite orders making two units as one* moves in the direction of measurement and two opposites as one retain the same order. But in the *individual unit of two together as one*, each constituent unit is of opposite order. Thus, in the second method, the progressive measurement of two units of opposite order together as such moves in the direction

of measurement and they may maintain parity of two opposites in the direction of measurement. In the first method only single unit was moving retaining the same order in the direction of measurement; here it would be the case of conservation of parity of one identical but which is only half of the former. This is the essential difference between the two methods of approach.

It would be interesting to see in the following that if an analysis of the magnitudes of numerical digits would be made in terms of 3 directional space time coordinates derived from the configuration of regular tetrahedron and the magnitudes attributable to each type of coordinates, it would be seen that the numerals themselves follow the same kind of cumulative magnitudes in terms of space time coordinates in the direction of increasing magnitude as was seen in the second method of measurement by red-black rod.

We have already shown in the article entitled "Geometry of space time configuration" that the configuration of regular tetrahedron associates within its constitution unique data which, by their proper application, can convey possibly the entire information about the universe. In the following the three directional space time coordinates from the configuration of regular tetrahedron has been applied to analyse the magnitudes of numbers as resultants of the constituent coordinates acting and reacting in opposite to describe the cumulative numerical magnitudes.

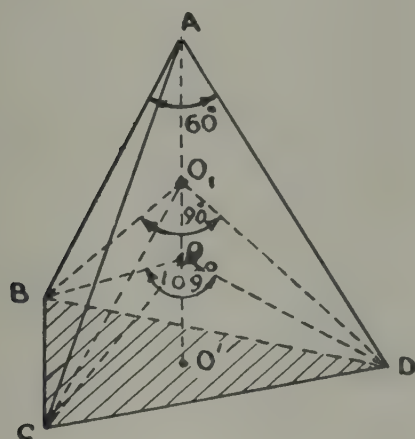


Fig. (a)

Take figure (a) which is a regular tetrahedron and whose base is equilateral triangle BCD, apex is A and the altitude is AO'. There are 3 distinct 3 directional coordinates from three distinct reference positions namely A, O₁ and O lying on the altitude from which 3 directional coordinates diverge towards the 3 positions B, C and D. The first reference position is the apex A

itself which is one of the positions of the evolved tetrahedron like any one of B, C or D. The coordinates from A towards, B, C and D diverge from A at an angle of 60° to each other. This 3 directional coordinate has been called 60° coordinate. Another three directional coordinate towards the positions B, C and D diverge from the centroid of the tetrahedron O. The angle between the coordinates is 109°. This has been called 3 directional tetrahedral coordinate. There is another position O₁ on the altitude which is mid way between A and O' from which the coordinates towards positions B, C and D diverge at right angles to each. This is 3 directional rectangular coordinate. The significant aspect of these 3 coordinates is that while the 3 coordinates from the specified positions on the altitude aspects or cover the identical triangular face BCD, the distance from O', the mid triangular face BCD, is 1 for tetrahedral coordinate, 2 for rectangular coordinate (reference position O₁ is at a distance of 2 units from mid face O') and 4 for 60° coordinate which is the distance from A to O' to mid face BCD. These numerical magnitudes of 1, 2 and 4 to the mid point O' of the base triangle relative to the 3 coordinates are extremely important and significant in quantitatively defining and describing the space time relationship of coordinates in the definition of magnitudes of various configurations which will be evolved due to action and reaction of these coordinates. Thus under constant magnitude of frame of reference of the regular tetrahedral configuration, the 3 coordinates can be described numerically by 1 for three directional tetrahedral coordinate, 2 for three directional rectangular coordinate and 4 for a three directional 60° coordinate in one direction. If the space time configurations would conform to regular tetrahedral structure retaining constant magnitude all through out, these significant magnitudes of digits as units of numerals should remain valid. Under these conditions, the significance of coordinates defining the magnitude of digits is discussed in the following with the help of the figures from (a) to (k). The triangular faces involved in these figures however, which are shaded, are all identical—this equilateral triangular face correspond to the triangular face of the unit tetrahedron whose magnitude remains constant in all the progressively increasing magnitudes of configurations synthesising magnitudes of digits.

Magnitude of 1

Figure (b) indicates one 3 directional tetrahedral coordinate from the centre of the tetrahedron (regular) towards three positions of a triangular face. The dis-

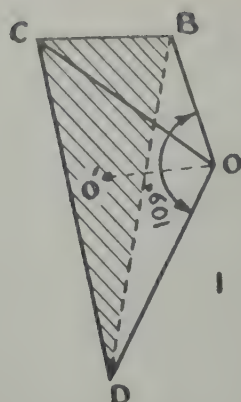


Fig. (b)

tance between the centre and the mid face is of magnitude of 1 as unit. In the configuration of regular tetrahedron, no other point of position in the evolved configuration would be four which is lower than this magnitude of distance from the centre. The angle between the coordinates OA, OB and OC is 109° .

Magnitude of 2

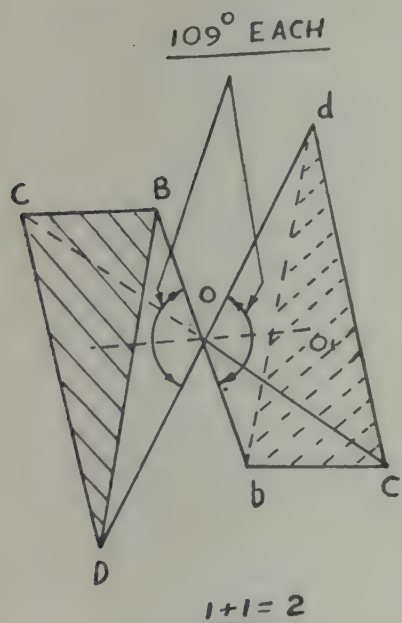


Fig. (c₁)

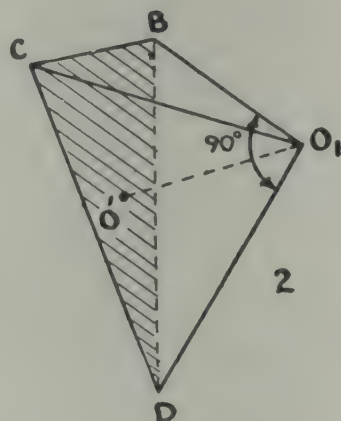


Fig. (c₂)

In Fig. (c₁) the coordinates of the position from O₁, which is the mid point of the altitude in the tetrahedral configuration the coordinates O₁B, O₁D and O₁C are at right angles to each other and the distance from O₁ to mid face is 2. In Fig. (c₂) is shown another method of synthesis of magnitude of 2 in which tetrahedral coordinates of magnitude 1 each act in opposition through a common point.

Magnitude of 3

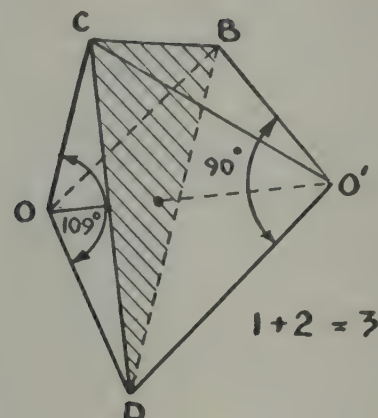


Fig. (d)

In Fig. (d), the magnitude of 3 is derived from the two coordinates of which one is 109° and the other is 90° . These two coordinates, when they act and react with each other in opposition at common face BCD, the magnitude of distance between the two reference points O and O₁ is 3. The configuration generated by action and reaction of the tetrahedral and rectangular coordinates which together make magnitude of 3 units of digits is not apparently divisible into identical parts of halves.

Magnitude of 4

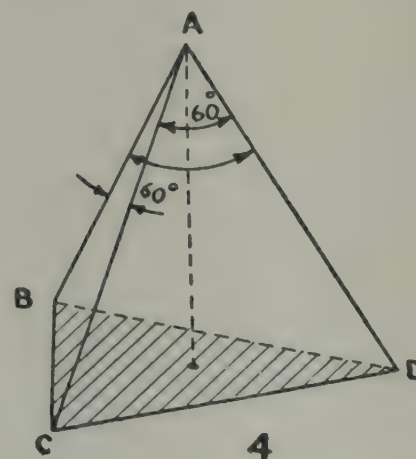


Fig. (e₁)

In Fig. (e₁), the configuration of the regular tetrahedron itself has, with respect to one position A, 60° coordinate towards the other 3 positions B, C and D and the distance as altitude has magnitude of 4. This is, however, the configuration as a whole. The other alternative configuration (e₂) which is synthesised from 2 rectangular coordinates describe 4, as sum of 2 and 2

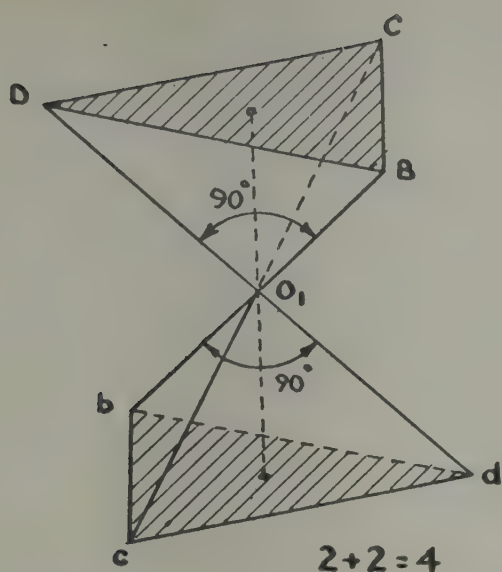


Fig. (e₂)

and each coordinate has magnitude of 2 the two together make 4. The digit 4, as may be seen in (e₁), can be considered as 4 as a whole and also may be considered to be made up of constituent halves as 2 and 2. But the latter two 2s are identical but opposites. Therefore, 2+2 which make 4, the two 2s are not identical but opposites although their magnitudes are identical but should be opposite in sign in direction to make a total of 4.

Magnitude of 5

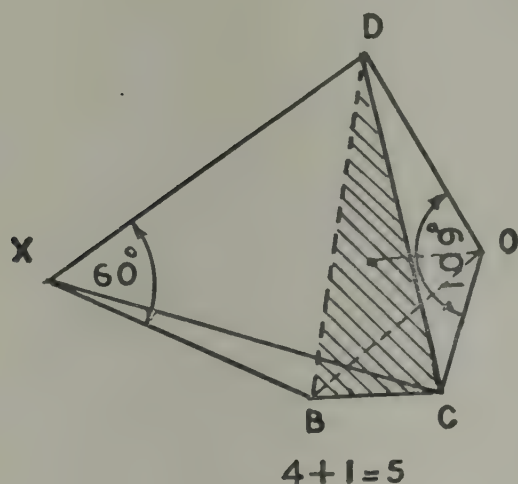


Fig. (f₁)

In this case, there are two alternatives, as shown in the configuration in Figs. (f₁) and (f₂). The digit 5 is an equilibrium configuration between the coordinate of 109° acting in opposition to 60° coordinate. 60° coordinate has magnitude of 4, 109° has magnitude of 1. The two together make 5. The digit 5 can also be consti-

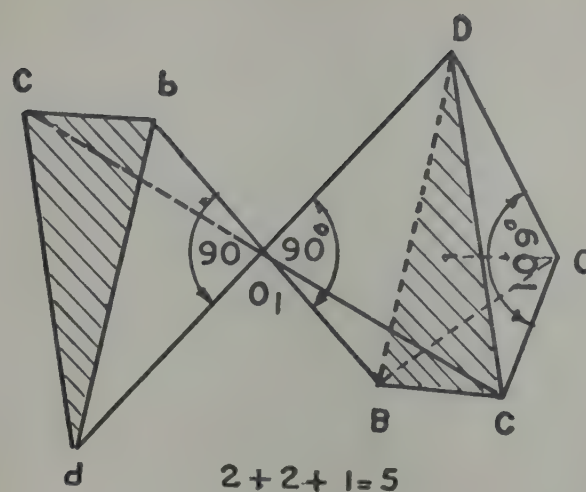


Fig. (f₂)

tuted of configuration due to 109° coordinate acting in opposition to one opposite pair of 90° coordinates. In this case, the analysis of 5 would be 2 and 2 for two rectangular coordinates plus 1 for the 109° coordinate.

Magnitude of 6

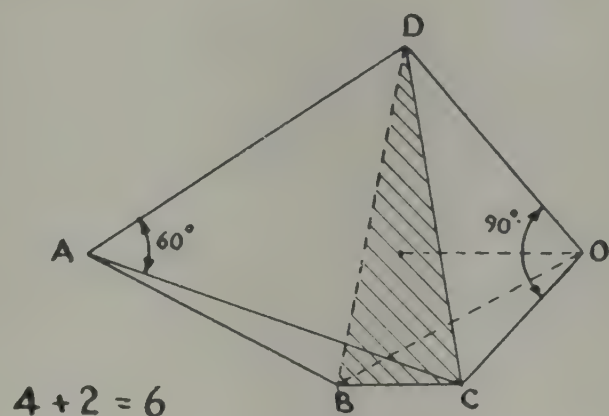


Fig. (g₁)

There are four alternatives (g₁), (g₂), (g₃) and (g₄). (g₁) is the equilibrium configuration of 6 due to the 90° coordinate acting in opposition to 60° coordinate; 2 for the former and 4 for the latter acting in opposition make 6. Fig. (g₂) shows the synthesis of magnitude of digit 6 from 3 equal magnitudes of 2, each of which is a rectangular coordinate acting in opposition as 2, -2, +2. All the 2 digits in Fig. (g₂), it may be seen from the configuration, are acting in opposition in succession. In Figs. (g₃) and (g₄), the synthesis of digit 6 from two halves of magnitudes is shown. Each of 3 is composed of 109° coordinate acting in opposition to 90° coordinate. Here again the two halves are identical magnitude in 3 but each equals to opposite in sign in direction. But in (g₃) two halves each of 3 acts in oppo-

sition through a common point of positions of 60° coordinates and in (g_4) through a common point of position of 109° coordinates.

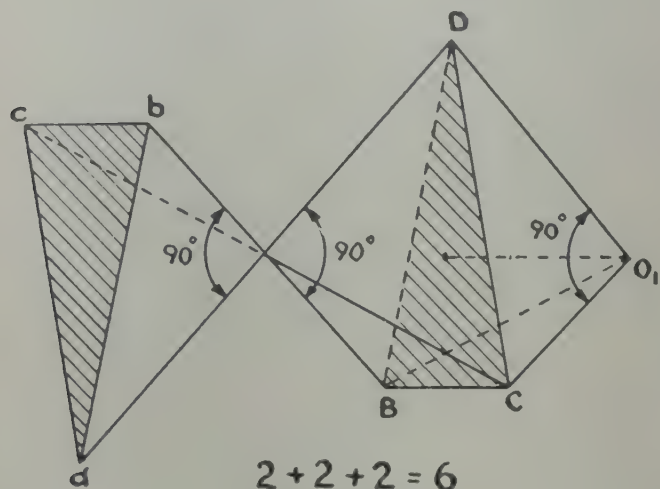


Fig. (g_2)

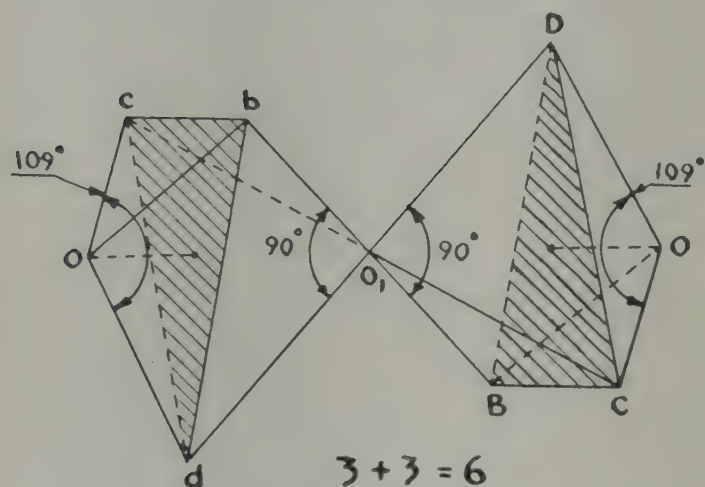


Fig. (g_3)

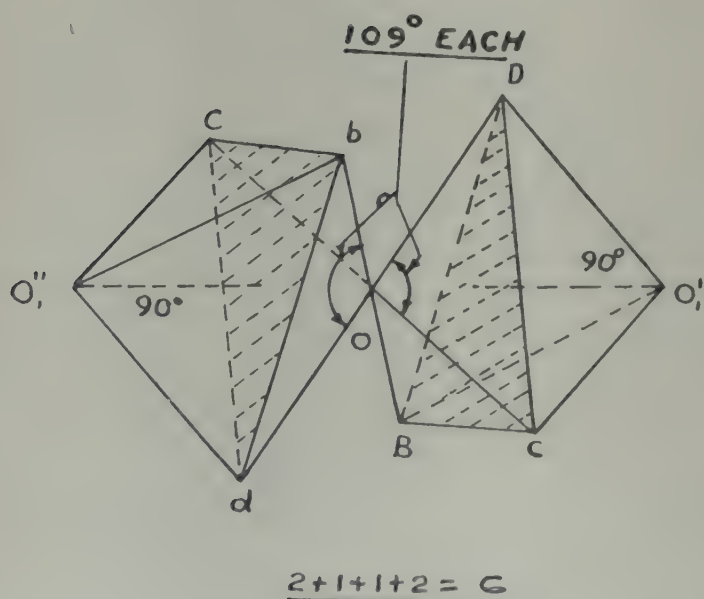


Fig. (g_4)

Magnitude of 7

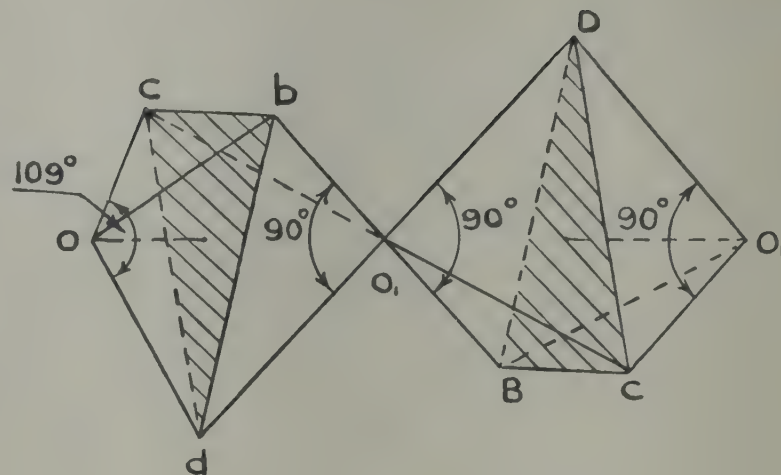


Fig. (h)

Constitution of the configuration of magnitude of 7 could be seen from the Fig. (h) as being generated as an equilibrium configuration between a pair of opposing 90° coordinates against another pair of opposing 109° and 90° coordinates. The digit 7 is indivisible into identical parts. There could be other arrangements also with configuration of 7.

Magnitude of 8

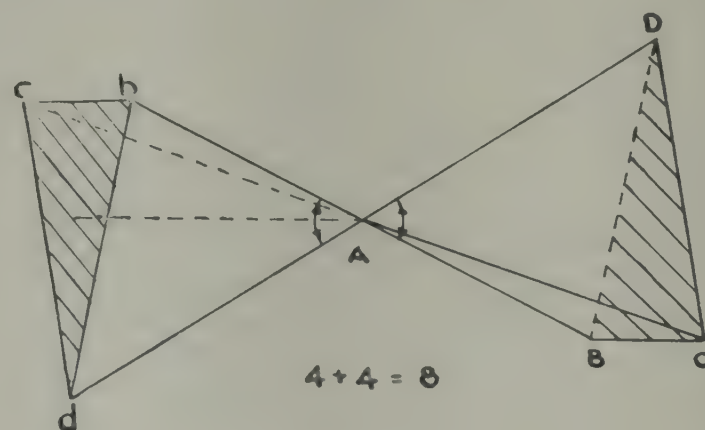
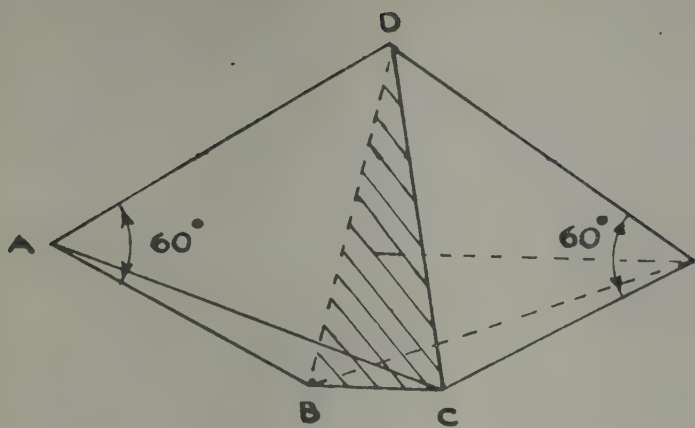


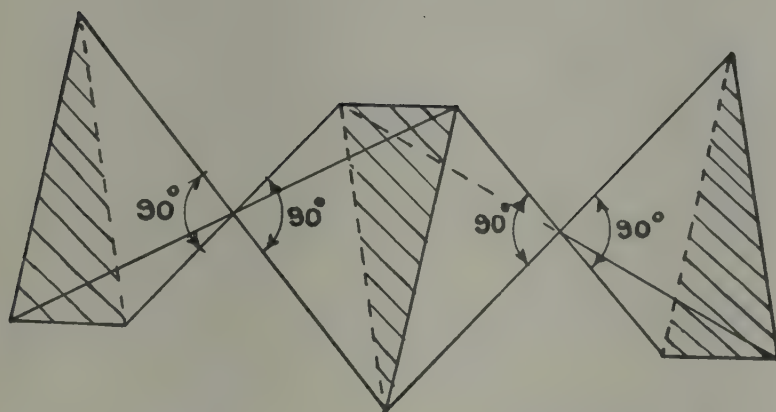
Fig. (i_1)

In magnitude of 8, four alternative arrangements are possible. In Figs. (i_1) and (i_2), the configuration of the digit is the resultant of action and reaction between two 60° coordinates and the other alternative in Figs. (i_3) and (i_4) is between two pairs of opposing 90° coordinates. The coordinates of the various configurations of 8 would show how the digit 8 can be split into two halves of 4 and 4 or 4 number of 2s.



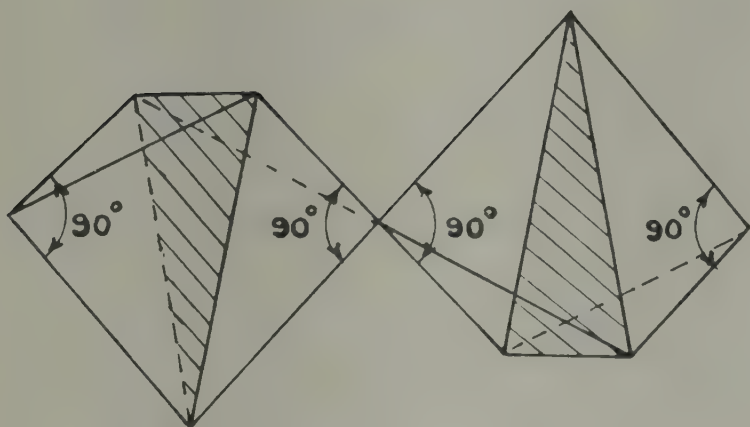
$$4 + 4 = 8$$

Fig. (i₂)



$$2 + 2 + 2 + 2 = 8$$

Fig. (i₃)



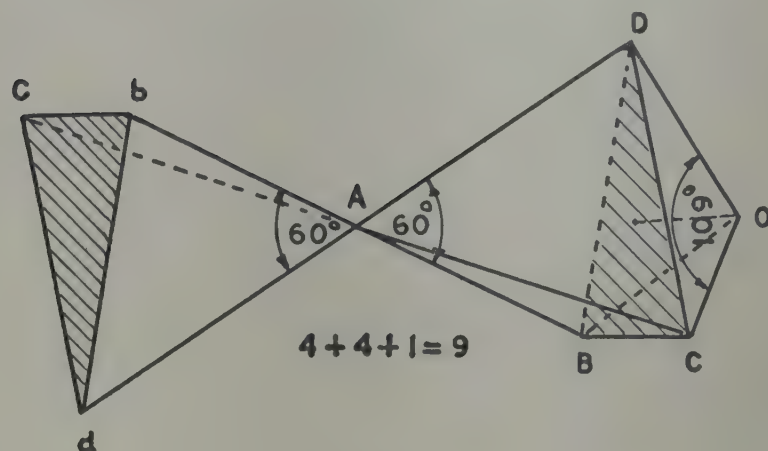
$$2 + 2 + 2 + 2 = 8$$

Fig. (i₄)

Magnitude of 9

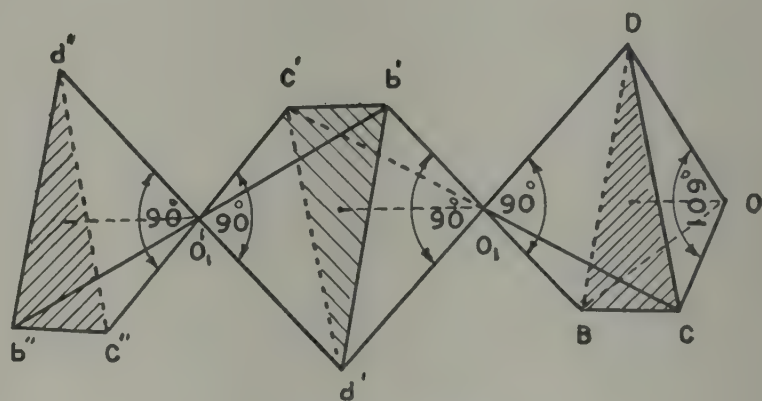
3 alternatives are shown in Figs. (j₁), (j₂) and (j₃). The configuration of 9 as in (j₁) has been shown as a pair of opposing 60° coordinates in equilibrium with one 109° coordinate. (j₂) is the equilibrium configuration with two pairs of opposing rectangular coordinates in equilibrium

with one tetrahedral coordinate. (j₃) analyses the magnitude of configuration of 9 as a pair of opposing rectangular coordinates and is in equilibrium against a 60° coordinate from one direction and 109° from opposite direction.



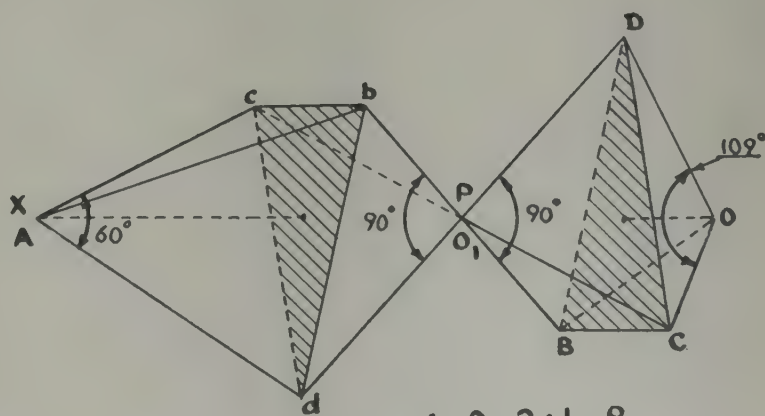
$$4 + 4 + 1 = 9$$

Fig. (j₁)



$$2 + 2 + 2 + 2 + 1 = 9$$

Fig. (j₂)



$$4 + 2 + 2 + 1 = 9$$

Fig. (j₃)

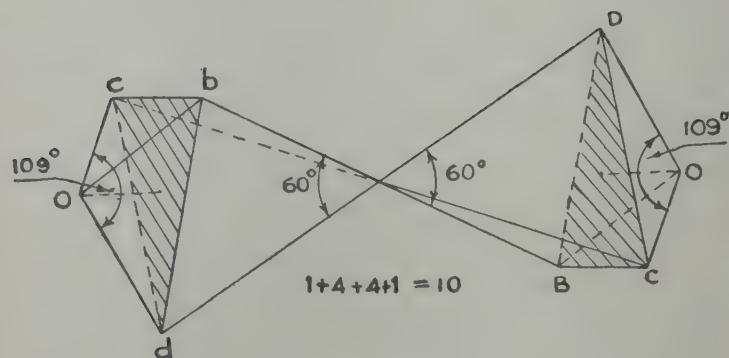


Fig. (k₁)

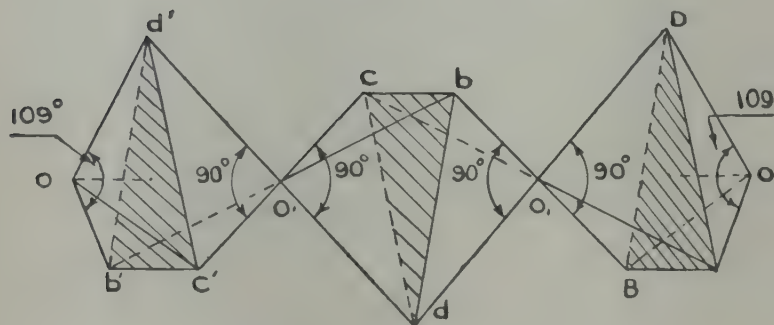


Fig. (k₂)

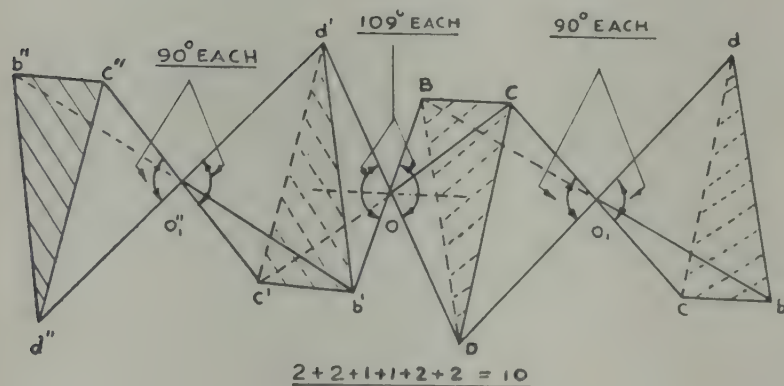


Fig. (k₃)

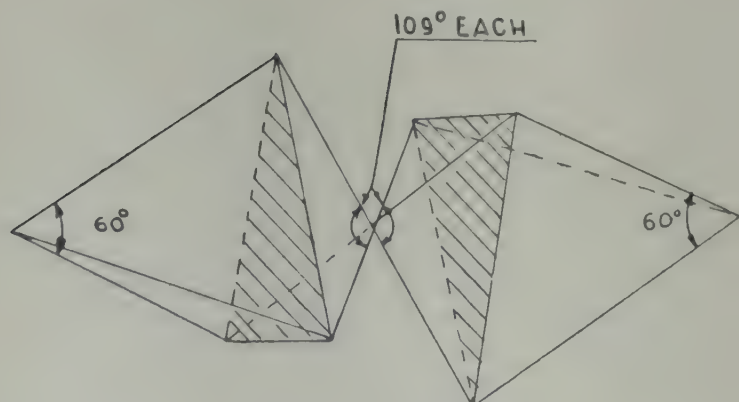


Fig. (k₄)

Three alternatives in Figs. (k₁), (k₂), (k₃) and (k₄) have been shown. In (k₁) and (k₃) equilibrium of two 5s each 5 is constituted of one 109° coordinate in opposition to 60° coordinate. In (k₂) two opposite pairs of rectangular coordinates reacting against two tetrahedral coordinates from opposite directions make total of 10.

Special Significance of the Magnitudes of Configurations of digits 9 and 10

The configuration of the digit 9 in Fig. (j₃) would show its significant relevance in the configuration of the universal wave. In the universal wave in one direction from centre O, tetrahedral coordinate acts and from the boundary X 60° coordinate acts in opposition to it and they establish equilibrium of equality through a pair of opposing rectangular coordinates. Two rectangular coordinates establish equilibrium of two equals. It is significant to mention that in the configuration of the universal wave only one tetrahedral coordinate is operative and that too from the position at the centre of the wave. The position (P) in Fig. (j₃) is the position of equality equilibrium between two opposing rectangular coordinates each of equal magnitude of 2 but the two 2s are of opposite sign. The distance OX constitute 9 units of magnitudes. But in Fig. (k₁) it will be seen that 10 is the established equilibrium. Here the position O corresponds to the centre of the universal wave and X correspond to position which should be finite limit of the universal wave as 9 units. But X' corresponds to a position, to get which an identical tetrahedral coordinate of opposite sign as that at O has been added to establish the complete equality equilibrium. This combination, however, is not permissible in the universal configuration where the finite limit is 9. Any limit beyond that, i.e. location beyond X would be found at which the fundamental dimension which starts the creation of configuration of the wave from O with highest magnitude of intensity of coordinate should have nil magnitude, its finite least magnitude (which is 60° coordinate in this case) could be only up to X. Whereas the derived dimension starting with least magnitude at O would progressively increase upto the finite maximum at X. Beyond X, namely at X', which is beyond the finite limit, the derived dimension would assume infinite magnitude whose coordinates could be tetrahedral 109° but the magnitude of the fundamental — would fall to nil. This significance should be understood, because the significance of decimal system is derived from the configuration of the universal wave.

The definition of the magnitudes of numerals as explained in the above would show that the magnitudes

of configurations of numbers or digits in order of progressive increase in their magnitudes actually have the forms of waves of equilibrium configuration generated by opposing coordinates which constitute the total equilibrium magnitude. In the direction of increase or decrease of magnitudes action of one coordinate is immediately followed by the reaction of the other and the process repeats giving the nature of the total equilibrium magnitude as configuration of wave structure, composed at each stage due to action and reaction of two opposite coordinates.

Another Approach

Numerical evolution at equilibrium and evolution of equilibrium configuration of the spherical wave conforms to tetrahedral evolutionary principles. When an evolution takes place due to a fundamental dimension, derived dimension is also simultaneously generated. The two together by their action and reaction establish the equilibrium. Before the start of the evolution, the fundamental dimension had an imaginary tetrahedral configuration in which the central position assumes infinite intensity of fundamental and the four vacant positions made only imaginary tetrahedral configuration of four positions since the positions contained nil magnitude of derived but the centre contained all the fundamental only. This is the concept of fundamental in its abstract state of existence which is a concept of imaginary configuration where neither the infinite magnitude of the fundamental nor the nil magnitude of associated derived is amenable to finite comprehension.

The concept of finite unit of least magnitude, equilibrium concept can be deduced from Fig. 1. Unit of least equilibrium magnitude can be realised through the equilibrium reaction between the finite magnitudes of fundamental and derived such that the fundamental would be finite highest at the centre and finite least at the boundary of the finite spherical wave and the magnitude of the derived should be finite highest at the boundary and finite least at the centre. The equilibrium reaction of these two opposites in the spherical wave configuration would produce the least magnitude of unit concept along the equality equilibrium ABCD. Thus if the symbol 1 would be considered as the least conceivable unit of magnitude of equilibrium, then with respect to the fundamental and derived at the centre and the boundary, it would be either nil or infinite respectively, both of which are beyond conception. Therefore, the concept of equilibrium configuration of least magnitude of numerical unit contains

magnitudes, one nil and the other infinity so much so that the further magnitude of units of increased size or intensity of number would only start from the state of completed evolved equilibrium of 1 occupying central tetrahedral positions in which neither the centre nor the boundary would come into the picture in configuration. Therefore, for further development of the concept of unit magnitude the direction of increase would start from this symbol of concept of least unit of magnitude. It should, however, be clear that in order to retain tetrahedral configuration the equilibrium of least magnitude of unit must have higher than 1 at the centre and less than 1 at the boundary; its opposite would have less than 1 at the centre and higher than 1 at the boundary. The equilibrium magnitude of unit thus depends on the equilibrium magnitude of the configuration. As the equilibrium magnitude of configuration increases the equilibrium magnitude of units also increases. Significance of equilibrium magnitudes of unit in configuration is thus relative vis-a-vis magnitudes of nil and infinity at the centre and boundary of the configuration of the universal wave. Evolution of equilibrium magnitudes would therefore follow with magnitude of configuration as follows:

Less than 1				1				Higher than 1					
1	1				2					3	3		
1	1	2	2		3		4			5	5		
1	1	2		3	4	5		6		7	7		
1	1	2	3	4	5	6	7	8	9	9			
Boundary				Equality				equilibrium				Centre	

Let us start from the equilibrium configuration of least conceivable magnitude. If in this equilibrium of tetrahedral configuration, the symbol of least magnitude is 1, in whatever way the four positions would be seen, relative to one position, the other 3 would be identical but varying in orbit. Therefore, in the evolutionary development of the increasing magnitudes of units, the equilibrium would be established in which the positions must conform to 1 : 3 proportion (This necessarily implies that radial evolution in four directions is an impossible task in perception). They can be only imaginary if the evolutionary development would be considered in the radial context, in order to be amenable to our capacity for conception, it has to be in one radial direction and must be observed or perceived by taking up a position at the evolved configuration of 4 positions. In latter case the uniformity or isotropy of 1 : 3 will be maintained and not 1 : 4.

The former could only be perceived, by taking up one position relative to 3 evolved.

Now take the first case of evolution from the concept of least magnitude of unit of positions having tetrahedral configuration. The simplest case would be as in Fig. 5, where, in the evolved tetrahedral configuration of the spherical wave, the four outer tetrahedrons W, X, Y and Z vis-a-vis the central one ABCD are themselves units of tetrahedrons maintaining a tetrahedral configuration amongst them. Only points of positions are substituted by tetrahedrons. Suppose these are considered from one of the positions for observation, say tetrahedron belonging to Y in Fig. 5(a). The other 3 tetrahedrons X, W, Z are all identical and retain 1 : 3 ratio. When these four tetrahedrons are in equilibrium they have necessarily to be accommodated in the universal wave such that their triangular faces opposite to WXYZ form the four faces forming central tetrahedron having the same spatial magnitudes as the outer ones. For equilibrium, in this case, all the four tetrahedrons have their own centres, all at equal radial distances of two units from centre of the wave.

This may be described in many ways by taking tetrahedral models. For example, let the central tetrahedron and ABCD be so placed face to face with the tetrahedrons W, X, Y, Z that the apex Y is situated on the plane of paper and the position A of the central tetrahedron is vertical relative to Y. Starting with the tetrahedron Y as 1 and central tetrahedron as 2, 3 would correspond to the tetrahedron XWZ. Thus, these 1, 2 and 3 form one line of case 2. The opposite case would substitute the position Y by A, Y being

placed vertically above A; then the tetrahedron Y would have 3 tetrahedrons along 3 of its triangular faces and one tetrahedron ABCD along the fourth face. If the tetrahedron ABCD is 1 and the 3 other tetrahedrons along 3 faces of the tetrahedron YDCB are in the reverse positions, the two opposite arrangements can be presented as 3, 2, 1. Thus case 2 would be reproduced as

$$\begin{array}{ccc} 1 & 2 & 3 \\ 3 & 2 & 1 \end{array}$$

In this arrangement, at equilibrium between these two opposite configurations, there are altogether another 8 tetrahedrons involved. The significance would be the same if one tetrahedron of four positions would have reversed between opposite phases; that would have also generated 8 positions of cube.

This equilibrium of two between 1 and 3 can be illustrated by further examples; e.g. take 3 tetrahedrons so arranged that their three triangular faces, one from each, generate a fourth tetrahedron and similarly, another set of 3 tetrahedrons with their faces, generating another fourth tetrahedron. Now, if the fourth tetrahedron from the two sets are placed face to face, that would also present an equilibrium of 2 between 1 : 3.

Thus we can see that, if an equilibrium combination of tetrahedral configuration would be generated, the equilibrium must exist between two opposite arrangements and the number of tetrahedrons involved would depend on magnitude and number in the overall configuration and the number of units of tetrahedrons making them but the sum total effect of number of units must be retained as 1 : 3. This will be seen in the various cases of numerical evolution as follows:

Boundary	Intermediate states (Heterogeneous)			Equality equilibrium	Intermediate states (Homogeneous)			Centre	Ratio
< 1				1				> 1	< 1
A > 1				1				< 1	> 1
< 2 = 1				2				3 = > 2	
B > 2 = 3				2				1 = < 2	$\frac{1}{3}$
< 2 = 1	2			3	4			5 = > 4	
C > 4 = 5	4			3	2			1 = < 2	$\frac{2+1}{5+4} = \frac{1}{3}$
< 2 = 1	2	3		4	5	6		7 = > 6	
D > 6 = 7	6	5		4	3	2		1 = < 2	$\frac{1+2+3}{7+6+5} = \frac{1}{3}$
< 2 = 1	2	3	4	5	6	7	8	9 = > 8	
E									$\frac{1+2+3+4}{9+8+7+6} = \frac{1}{3}$
> 8 = 9	8	7	6	5	4	3	2	1 = < 2	

Another mode of tetrahedral evolution, which would demonstrate that the numerical evolution starting from least magnitude of concept as digit need only be 9 different magnitudes for an evolution is as follows: in a regular tetrahedron, the line joining the apex and the centre falls normally on the mid point of triangular face opposite to the apex. If the line joining the centre to the apex is 3, the perpendicular distance from the centre to the triangular faces is one. If 2 regular tetrahedrons are placed face to face, each centre position, opposite the common triangular face between the two, is at unit length of distance from the mid point of common triangular surface. The distance between the centres of the two tetrahedrons is two units and the distance between the centre of one tetrahedron to the apex of the other tetrahedron is 5 units of length and distance between mid point of common surface to apex positions is 4 units of length. If the tetrahedral configuration of the universal wave, as in Fig. 5, is taken, it would thus be seen that distance between the centre and any of the apex positions WXYZ is of 5 such units of distance and the diameter of the spherical surface is 10 units.

This may seem somewhat contradictory to the configuration of universal wave shown in the Fig. 5 in which the radial evolutionary states have been shown as 9, which with further two: one the central point and the other the boundary of the evolutionary wave, together make 11. This apparent discrepancy would be resolved if the revolutionary wave would be considered in proper perspective taking into account the variability of the positions at the various states, viz. the centre, the boundary and the equality equilibrium relative to one other, depending on the equilibrium magnitudes up to which the wave has evolved. For example, when the fundamental dimension was in an abstract state of existence and only retaining an imaginary tetrahedral configuration, in that state magnitudes of matter intensity, time intensity, configurational magnitudes of space, variability, etc. are nil. Under this condition, the 3 states—centre, boundary and equality equilibrium—all would have merged as if to the central point. But when the fundamental dimension assumes a finite configuration of progressively increasing magnitude, the previous points of positions of equilibrium assumes the state of equality equilibrium of 1, 2, 3, 4, 5, etc. The boundary, with increase of magnitude, recedes progressively far away from centre. Thus the point position of fundamental in association with nil derived in (A), in the next case would be (B).

The next evolution is B, which is an equilibrium of 2,

in 4 radial directions. The next evolution corresponds to case (C) which is equilibrium of 3. Similarly, equilibrium of 4 and 5, in one radial direction has been shown at (D) and (E).

At the starting stage the point of position retains tetrahedral configuration with the fundamental occupying the centre and the 4 positions having nil magnitude of derived. In this state, the centre, the boundary and the equality equilibrium of the spherical wave all condense to the point. In (A) the configuration assumes equilibrium magnitude of 1 in which the centre has the higher magnitude of fundamental dimension than 1 and the boundary has the higher magnitude of derived than 1. In the next state (B) the equilibrium magnitude of configuration has increased to equilibrium magnitude of 2, which is the equilibrium of finite highest and least of 3 and 1 respectively. These 3 states would lie between the centre O and the boundary of the wave. In (B), if the boundary and the centre states would also be taken with 1, 2 and 3, there would be altogether 5 states, out of which only 3 states are finite and conceivable. Similarly in (C), finite digits are 1, 2, 3, 4 and 5 having equilibrium of 3, at which the equality equilibrium has 5 finite number of states and along with the centre and boundary, the total will be 7. In (D), equilibrium of 4 has 7 finite states, but 9 including the centre and the boundary. The equilibrium of 5 in (E) has 9 finite states, with centre and boundary, the total is 11.

In terms of numerical digits, further evolutions will be repetitive of this. The above explanation should remove the apparent discrepancies between Figs. 5A and 5C with respect to numerical evolution by assigning units of radial length when describing the spherical wave.

The apparent discrepancy can also be explained as follows, considering the configuration of the wave with its associated variabilities:

Take Fig. 1 and start from the centre. Imagine the centre with 4 positions, progressively expanding. The first state would be to describe a unit which will be the radially normal to the triangular faces of a, b, c and d. The positions, while describing the space positions a, b, c and d, have also undergone simultaneous variation in the direction of the expansion. Thus by the time the configuration progressively describes 2 through 3 and 4 to 5, position of 5 would have been reached 5' so that, with further increase of time through 6, 7, 8 and 9, the original position which was the starting point would again be arrived at.

In the same way, if an isolated self-sufficient equilibrium would be created between two tetrahedrons placed face to face, the two opposite apex positions are situated at 8 unit distance. The equilibrium is established at the mid point of the common triangular face. From the position of equilibrium, on either side towards the 2 apexes, are 4 units of distance. When the two tetrahedrons had least magnitude of space both the opposite apexes would have condensed to the centre O. As the magnitudes will increase to 1, 2, 3, 4, etc. the position 4 of the apex of first will move to position of 4' of the second wherefrom the magnitude will increase towards 5, 6 and 7 and the 8th position will occupy the starting point O. This process will go on repeating. This is one way of expressing the octate system. In the context of spherical wave, however, the various stages in the direction of magnitude would follow the radial course in the spherical wave in which the first starting point assumes the centre of the spherical wave and ultimately ends up to points at the boundary.

The thesis that there is only a maximum of 9 different states in an evolution beginning between and ending in a tetrahedral evolutionary process could be demonstrated by actual models, from various angles and aspects. It may be points of position; or the various sides and faces with respect to a position or the various triangular faces with respect to one another; or the various unit tetrahedrons in various arrangements with respect to one another, or even the various directions involved in association with evolved positions or with the centre of a unit tetrahedral configuration, etc. If one would carefully look into the various Chakras (चक्र) and Kundalis (कुण्डलि), viz. Shriyantra and other Kundalis one would see the numerous attempts to represent the tetrahedral evolutionary configuration in ancient India on a plane of paper (Pati). Those descriptions have not been able to invoke sufficient interest in modern times because the fundamental law and the main coordinating and guiding principles which governed these and which led to these kinds of configuration, have been forgotten and little significance is therefore attributed to them in present times.

Decimal System of Numbers and Ordinals and Cardinals

From the discussions in the above on the development of configuration of evolution, starting from a point of position to completion at the boundary of the evolutionary wave, it would be established that the universal equilibrium can only reach maximum equilibrium of 5 for one isotropic evolutionary wave which has 9

finite different spherical-surface states depending on relative magnitudes of intensities of fundamental and derived dimensions and the location and magnitude of the spherical surfaces. The manifestation of the complete wave, begins from a position of point concept at which the magnitude of surface configuration is nil and ends up at the boundary where the magnitude of evolved configuration could be infinity. The magnitude of intensity of the derived dimension as well as the magnitude of evolved configuration increase in steps or stages with increase of magnitudes of surface configuration from one state to another in increasing order of magnitude from centre to boundary through the 9 states. Equilibrium is maintained at the 5th state from the centre and the boundary.

Ordinals and Cardinals

The nine spherical surface states in the configuration of the spherical wave, in addition to the centre and the boundary are actually the various states of potential gradients of either the fundamental or the derived dimension; if the spherical wave is of energy, matter space and time dimensions then the potential gradient along these states will be of increasing magnitudes of derived towards the boundary, starting with nil at the centre. If the potential gradient would refer to the fundamental dimension energy then the gradient would be in the reverse direction, i.e. starting with nil at the boundary it will increase to infinity at the centre. The magnitude of configuration of space field as well as intensity of time dimension for the wave follow the same direction as the potential gradient of matter, and the gradient of magnitude of space intensity and magnitude of configurational time would follow the direction of potential gradient of the fundamental dimension energy. During evolution, the manifestation starting from the centre, would take place in steps, *in terms of magnitude of intensity of matter or magnitude of space configuration* through 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th and ultimately end up in the 10th, i.e. the boundary of the wave. The states, in order of sequence, may be designated as ordinals and refer to the potential states. If the designation of the ordinals would start from the centre then the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th and 10th at boundary would correspond to the energy potential or energy intensity states in decreasing order of magnitude. In terms of magnitude of matter intensity, these are in increasing order of magnitude. These states in the universal spherical wave therefore refer to the sequence of steps in the spherical wave indicating the magnitude of

intensity or potentials of dimensions of which the wave is composed of.

On the other hand, the difference in magnitude between the intensities of states would give the actual number of units through which the change has taken place; thus, between the centre and the first state, the unit of magnitude of matter formed is one. Between 1 and 2,—2 magnitudes, between 3 and 4,—4 magnitudes. Thus, from the first to the 9th—9 units of magnitudes of matter should develop. In terms of magnitude of spatial configuration 9 unit space magnitudes have developed. To arrive at the boundary the matter will require to increase its magnitude to 10 units. These are the cardinal numbers as magnitude of units.

Decimal System

With respect to the evolved configuration, the whole evolution starts from point concept which, actually in terms of the magnitude of derived or in terms of the magnitude of the configuration of the evolutionary wave, has no meaning, having nil significance of finiteness in it. The substantial or finite comprehensible evolutionary stages start with the association of least magnitude of finite digit 1 through 2, 3, 4 to the equilibrium 5th and from it, again through 6, 7, 8 and 9 in order of increasing magnitude till 9 which is the finite highest amongst the distinct states comprising the universal wave. Beyond 9 is the boundary which is incomprehensible in finite conception. Thus, from the starting position of central point, the evolution, having passed through 9 finite distinct intensity or potential states in the evolutionary wave of increasing magnitude in the present configuration, ends up into infinite space magnitude of nil intensity in the 10th state, which is the boundary of the present wave; where one evolution of spherical wave would be completed and which can be logically symbolised by a circle on plane of paper. At this state, the derived dimension would assume magnitude of infinite intensity, having nil magnitude of time configuration and nil magnitude of space or energy intensity. This would be the starting point of another evolution in which the present derived dimension will become the fundamental and again, if the next evolution would be also isotropic and tetrahedral, a similar wave will be generated with similar nature, characteristic and variation of magnitudes of dimensions like these constituting the present universal spherical wave. Further progressive development will be repetitive. In the next evolution, the new fundamental dimension will also require to be associated with some derived new dimensions for the next evolution which

would again, though newly created finite states of increasing magnitude of the configuration in the wave, would end up into the second next boundary of evolutionary wave as circle. This will be repeated for subsequent evolutionary waves.

Now logically what has been described in the above can numerically be described in the following. The starting state as *cause* would be simply a *point of position* which, in terms of the magnitude of configuration of the wave, it is concerned with, would have no significance. But that point of position has great significance in what follows in the sequence of development potentiality and of the derived (as well as fundamental) dimension. Thus the starting point of no significance, relative to the derived would be a point. The various finite stages of increasing magnitudes in the evolution are progressively followed by finite digits, viz. 1, 2, 3, 4, 5, 6, 7, 8 and 9. The next stage after 9 in the evolution is the boundary which can be termed as one evolution signified by *one circle*. If this circle would be placed on the left side of point, it would indicate the number of evolution completed or preceded. Thus 1 signifies completion of one evolution and the magnitude of the configuration generated up to the first state of evolution following a point. The higher the magnitude of the digit on the right side of the point, the bigger the magnitude of configuration generated. After the evolution has developed from the 9th state, the tenth state would complete one evolution. The evolution starting from .1 through .2, .3 and .9 ends up in 1. In the next evolution 1.0 causes that and through 1.1, 1.2... would end up into 2 when two evolutions would be completed.

Proceeding in this way, completion of the nine evolutions will be designated by 9. The tenth evolution will start with 9.1, 9.2 and completed after 9.9. Now is the problem of designating the tenth completed evolution. The digit 9 on the right of the point would now become 1 which, when added to 9 on the left the point should signify ten completed circles. 1 indicated one complete evolution. Therefore one circle preceded by 1, i.e. 10 would signify ten evolutions.

The same evolutionary principles could also have been applied to nine evolutionary states in *one evolution* in the configuration of universal spherical wave to designate 10 in which case the first state would have started from .1 to 1, finally the ninth state as 8.1 to 9 and tenth for one evolution as 10 meaning thereby *one evolution* arrived at through nine states in one spherical evolutionary wave.

Octate System

The deductions in the above would clarify beyond doubt the basic considerations during the progressive development of the tetrahedral evolutionary concept (in the equilibrium of spherical wave in the theory of energy field) which led to the development of magnitudes in the conventional decimal system. It need not be emphasised that the decimal system was in vogue in India more than 2000 years ago and since the basic ideas have been developed from the concept of tetrahedral evolution must date back to the remote past. It will be shown in the subsequent sections that the decimal system was also most likely developed even prior to this and so also the octate system based on symbols counting only up to 4. It is not clear whether the decimal and octate systems existed simultaneously or the decimal system superseded the octate system. It will be shown later that the system of addition, subtraction, multiplication and division also were logical sequences following from the concept of tetrahedral evolution and the characteristic displacement of states and magnitudes as per the evolutionary wave in the decimal system. The name GUNANA for multiplication occurred even in Vedic literature and according to Sulb works, which are stated to be as old as 800 B.C., the term 'Abhyasa' was used for operations of addition and multiplication.

Since, as will be shown later, the method of various conventions adopted for carrying out the operations of addition, multiplication, subtraction and division, etc. were also all developed following the relative placement of digits as in the decimal system and nine symbols in the wave were used besides the symbols zero and point, it is clear that the numerals and the concept of digits and the modus operandi involving operation of different methods of increase or decrease in their magnitude by different means could only have been evolved after the concept of tetrahedral evolutionary wave was firmly established and understood in detail. Otherwise its adoption to carry out the operations in mathematics, or algebra in ancient India would not have been possible. As far as India is concerned, the tetrahedral evolutionary concept of spherical wave, its nature of configuration and the concept of increase or decrease of magnitudes by adopting symbols like digits signifying them and calculating increase or decrease of magnitude by various digits or by their cumulative addition or elimination depending on their placements in relevant states, originated from the basic knowledge and understanding of the concept of tetrahedral evolutionary wave.

Just like the evolution of the decimal system, as has been delineated in the above, the evolution of octate system also must have followed similar reasoning during its development. For example the number from 1 to 8 in the Bahmi system in ancient India were used to be written as:

I	II	III	X	IX	IIX	IIIX	XX	
for 1	2	3	4	5	6	7	8	respectively

Numerals in Sankhya Postulates in ancient India

In any book of ancient numerals or mathematics in ancient India these designations would be found. Similar to the reasoning we have employed before regarding the 2 symbols,—point and circle,—the octate system also must have been based on similar premises. The symbols presented in the above would testify this. 8 is signified as a repetition of X, signifying 4. X obviously signifies one tetrahedron of 4 positions. In the work entitled, "Theory of universal spherical wave and science in ancient India," Part III, it has been shown that the universal spherical wave of tetrahedral configuration and the various basic postulates thereof are almost identical to the basic postulates in Sankhya Science. In the basic postulates of Sankhya although 10 main states have been indicated, vide sloka Dasamaulikartha (दशमौलिकर्था), in its sloka Astauprakritaya (अस्तुप्राकृत्य) the number is 8. The significance of Prakriti (प्रकृति) is what is within perception, i.e. what is within the capabilities of being achieved in our perception. Unlike the states between the centre and the boundary, Prakriti is revealed in 8, between 2 poles, as has been described in the "Energy Field of the Universe and Atom, Part II"—in repetition of 7 digits. This process led the ancient numerologist to concentrate their attention to only 8 conceivable digits and not 10 in repetition. It is quite probable that, for quite sometime after the Sankhya postulates were propounded, ancient mathematicians perhaps attempted in developing the concept of 8, i.e. repetition in octate system. The decimal system is perhaps a later development when the development of numerals in the octate system did not meet with satisfactory explanations for everything as would be clear from the notations in the above designations of numbers in the octate system. The most important of all the symbols is X. This is the symbol of one developed tetrahedron. The symbols I, II and III are symbols of progressive number of radial state in evolution and when 4 states in evolution take place the tetrahedron is complete, signified by the symbol X. When another evolution starts after one evolution, again in terms of

radials these were placed preceding the symbol X. When 2 tetrahedral evolutions are complete, it is indicated by XX. From the analysis presented in this paper on the evolution of decimal and octate systems, it would appear that the development of the octate system preceded the decimal system. While on the discussion on origin of development of Numerals and the two systems, one cannot help referring to postulates of Sankhya Science in ancient India. Modern science after Newton originates from *physical perception* of a specific *phenomenon* of “fall of an apple”. Science in ancient India originated from *concept of fundamental in tetrahedral universal evolution* as embodied in postulates of Sankhya.

From the various associations of the digits with the original Sankhya postulates as 22 Sutras in Tattasamas (तत्समस्) of Kapila, it was whown in the “Energy Field of The Universe and Atom”, Part III (Ref. Technology, Vol. 2 (4), 1965) that these numerical digits, associated with the various sutras, actually, described figuratively tetrahedral evolutionary configuration in the universal spherical wave due to fundamental dimension in association with derived. The concepts of numerals or numbers were evolved along with discovery of the Sankhya postulates. Sankhya’s Purusha (पुरुष) is the fundamental dimension and Prakriti (प्रकृति) is the derived dimension. Purusha is one, Prakritis are 8 (a cubical position as equilibrium of two tetrahedrons) as is revealed in the Sutras Purusha and Prakriti. The former is the cause and the latter is the effect. Although it is not intended to go into detailed discussion on the individual slokas to show their indentify with the postulates of the spherical wave of the energy field which has already been done in the “Energy Field of the Universe and Atom”, Part III, in the present context, it is relevant to mention that the origin of the numerals in octates as well as decimals were evolved in the ancient times consequent on the discovery and development of the Sankhya Sutras, which was the origin of evolution of numbers, Mathematics, Geometry, Trigonometry, etc. Leaving aside the rest of the 22 Sutras in Tattasamasa, the following viz.:

Astadha Siddhi
Nabadha Tusti
Dasamaulikartha

would reveal that the significance of the numbers related to the different states in the spherical wave between the centre and the boundary. Astadha Siddhi signifies 8 finite steps amongst the states. The word Siddhi would signify those steps which are within

perception, i.e. these steps are capable of being perceived being finite in nature. Nabadha Tusti would signify that they are achievable in conception. Nine states cannot be realised in perception. Finally the sloka Dasamaulikartha states that there are ten main states in the configuration in conception. The 10th state corresponds to the boundary of the spherical wave but is not conceivable in the finite sense.

It may be noted that, in the ancient Indian literature, all the Chakras and Kundalis start from an origin from which they progressively emanate and start building the configuration. This is the Bindu (बिन्दु) or point concept.

Occurrence of Zero and Infinity in the Configuration of Spherical Wave

The distinction between the two symbols used in mathematics as Point and Circle in the background knowledge of the characteristics of configuration of the spherical wave and their real significance are not very difficult to appreciate. The point concept can be applied at the centre of the spherical wave as well as at the boundary. In the former, the point has association of 4 directions (having similar significance as degree of freedom or probability) and refers to position of a fundamental dimension like energy prior to the evolution of the wave. The positions of points in the latter case refer to that of matter at infinite potential situated at the boundary of the spherical wave. The point pertaining to matter has only 3 directions associated with it. The point signifies something of least magnitude of configuration but highest magnitude of intensity of its content. Thus the position of point of energy at the centre of the wave has least magnitude of configuration of space and highest intensity of energy; at the boundary, the position of point of matter has the highest magnitude of intensity of time and highest intensity of matter content.

Zero

Zero symbolised by a circle, signifying the boundary spherical surface of the wave, has infinite magnitude of configuration of space but only nil magnitude of its content the fundamental dimension energy. The magnitude of configuration of time, whose content is matter, tends to have its configurational magnitude of infinity towards the centre but there its intensity would tend to be nil. The magnitudes of configuration of space and configuration of time which tend to be of infinite magnitude at the boundary and centre of

the wave respectively but their contents, i.e. their intensities are nil, i.e. only imaginary at those locations.

The zero concept could thus be of one having highest magnitude of completed configuration with least magnitude of intensity of content. The concept of point, which is just the opposite, is one which has least magnitude of configuration but highest intensity of content. The two symbols are perfect opposites in significance.

While therefore, discussing the concept of zero, infinity and nil—this background analysis would be essential to appreciate their significance. The symbol zero does not necessarily mean nil as is conventionally taken to be. In terms of magnitude of size of configuration it should actually mean highest magnitude of radial space in the configuration of the spherical wave, expressed in terms of magnitude of configuration of space energy. But in terms of magnitude of configuration of time also it would mean highest with respect to configuration of matter dimension. In both cases, the magnitudes of something, whose content is nil or nothing, is obviously imaginary. Within the finite spherical wave, however, magnitude of zero would be relative to highest magnitude of finite space or time having association of least content in their configuration (i.e., biggest finite equipotential spherical surface state in the spherical wave).

The actual significance of zero, which is conventionally understood as nil, must have to be adjusted taking into account these aspects. These were probably the dominating points for consideration in the ancient times when the numerical digits were developed to build the edifice of mathematics, science and philosophy in ancient India.

Infinity

The concept of infinity should similarly be analysed for its true and relative significance. The magnitude of infinity can be relative to either the intensity of configuration of fundamental or derived dimensions in the spherical wave or the magnitude of size of their configurations in the universal wave. Magnitude of infinity can refer to the magnitude of configuration of time relative to derived dimension matter as its content or in terms of magnitude of intensity of the derived dimension. In any of these cases, the location of the position of infinity, relative to either the configuration of the fundamental or derived dimension, is either at the centre or at the boundary. Both are beyond finite magnitudes of the dimensions in the finite wave. So far as the present evolution is concerned, both the

magnitudes of fundamental dimension and the derived dimension are finite. They can be finite highest or finite least. There are nothing like infinity nor nil within the finite wave.

But the fundamental dimension has special significance of sequence relative to the finite wave, because the former is the cause of the subsequent finite wave, latter being the effect. The direction of change is from the least magnitude of the configuration of the fundamental where its own intensity is higher towards higher magnitude of its configuration where its own intensity is less. This is the direction of increase of magnitude of the *size of configuration* of fundamental and *intensity of magnitude* of derived dimension. In this particular direction of increase of magnitudes, the magnitude of intensity of derived dimension can assume magnitude of infinity when its location would be at the boundary of the present wave where the intensity of fundamental would be nil and the magnitude of size of space configuration would be infinite or imaginary. From that state, the derived dimension of the present evolutionary wave will achieve the status of cause for the next evolution for which it would become the fundamental dimension. The direction of magnitudes, which increases from the position of the cause towards the effect i.e. from the highest magnitude of intensity of fundamental towards least magnitude of its own intensity and towards highest magnitude of intensity of the derived, within the finite configuration of the spherical wave would start from finite least to finite highest. Magnitudes of infinity and nil refer to dimensions prior to or after the finite limits and hence they are not really relevant to the finite wave, since the magnitude of infinity relative to intensity of the fundamental dimension in the finite wave precedes the start of its finite highest and the infinite magnitude intensity of derived follows its finite highest limit.

So far as the present finite wave is concerned, *the direction of manifestation is from cause towards effect*. But the finite manifestation, however, has like the action of the fundamental dimension, the opposite reaction of the derived dimension. The direction of approach of the derived would be towards the cause, i.e. highest magnitude of fundamental and towards its own least. The directions of approach of the two dimensions are opposites. For the present finite wave, its link is from its cause and not the effect, the derived one can aspire only towards highest magnitude of the fundamental in the finite wave. Relative to the finite wave, the association of magnitude of infinity to the dimension of derived would be irrelevant.

If the magnitude of *infinity* would be imagined to be applied to the *intensity of derived*, this magnitude would be attributed to the effect of the cause for the present evolution whose location would be at the outermost boundary of the universal wave where the intensity of fundamental dimension of the present wave would fall to nil. In that event the entire existing evolution would dissolve and from that state the *infinite intensity of derived* would cause emanation of the next evolution assuming the status of fundamental dimension for that evolution.

The above analysis should clarify the various logical associations of magnitudes namely:

(a) Magnitude of zero (signifying nil) with the various dimensions and the size of configurations in the finite, infinite and nil states of existence in the universal wave.

(b) Association of infinity to various dimension and the magnitude of the configuration in the various states of finite, infinite and nil.

(c) The *rationale* of association of the magnitude of infinity or nil with finite magnitudes in various combinations.

In general, the association of the magnitude of infinity or nil with finite magnitude would be irrelevant. Even when infinity or nil would be attributable to the cause, association of these properties with the fundamental would relate to states of fundamental which either precedes or follows the finite manifestation. Infinity and nil cannot be associated with finite magnitudes in any form and in any state.

The finite wave would be concerned with the fundamental from its infinite pure form as concept of point which is the centre of a regular tetrahedron with all positions vacant as being the cause of the present wave

in which its position is the centre of the wave. The same fundamental, when it is in its infinitely diluted (equivalent to impure) state, exists at the boundary of the wave having nil intensity but in imaginary association with the infinite intensity of the present derived which would only be relevant for the next evolution. Thus, for the finite wave, the magnitude of infinity attributable to the property of the fundamental from which the finite wave is caused would either refer to its own intensity or the magnitude of its configuration. In the former case, if this would be positive, in the latter case that would be negative infinity. Actually, nil is just the opposite of infinity. If infinite intensity of energy at the centre is positive, then infinite magnitude of configuration of fundamental containing its nil intensity is negative infinity. In between these two states, the finite states of fundamental and derived *exist* in various combinations and proportions of their finite magnitudes as is figuratively shown below.

In the configuration of the universal spherical wave, the various equipotential surface states in the wave have been designated by magnitudes of dimensions from 1 to 9 in which the digits are actually relative numerical magnitudes of the units of dimensions at the various states. In this method, at all the states, the sum total of the magnitudes of fundamental and derived dimensions is constant. Instead of taking magnitudes of two dimensions together, if we take the magnitude of one dimension only, the cumulative magnitudes of units from 1 to 9 belonging to various states is explained in I in Table Z.

In the configuration of the universal spherical wave, the sum total of the magnitudes of dimensions at any equipotential surface state is ten at all the states. These magnitudes are actually relative numerical magnitudes of the units of the dimension. The representation

Boundary	Finite states									Centre
Nil or negative infinity with respect to intensity of fundamental	1	2	3	4	5	6	7	8	9	infinity—with respect to intensity of fundamental.
Infinity with respect to intensity of derived	9	8	7	6	5	4	3	2	1	Nil—with respect to intensity of derived.
Infinity with respect to magnitude of size of configuration of fundamental (space)	9	8	7	6	5	4	3	2	1	Nil—with respect to magnitude of size of fundamental (space)
Nil with respect to size of configuration of derived (Time)	1	2	3	4	5	6	7	8	9	infinity with respect to size of configuration of derived (Time)
Equality equilibrium										

Boundary											
	J	I	H	G	F	E	D	C	B	A	Centre
	1	1	1	1	1	1	1	1	1	1	I
(Cumulative)	10	9	8	7	6	5	4	3	2	1	
	10	9	8	7	6	5	4	3	2	1	II
(Cumulative)	55	45	36	28	21	15	10	6	3	1	
	100	90	80	70	60	50	40	30	20	10	III
(Cumulative)	550	450	360	280	210	150	100	60	30	10	
	J	I	H	G	F	E	D	C	B	A	IV
										1	0
									1	0	0
								1	0	0	0
						1	0	0	0	0	0
				1	0	0	0	0	0	0	0
			1	0	0	0	0	0	0	0	0
		1	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0
	10^{10}	10^9	10^8	10^7	10^6	10^5	10^4	10^3	10^2	10^1	
(Cumulative)	1111111110	111111110			111110		1110		110	10	

Table Z

towards increase of magnitudes to a limit or up to a state, retaining configuration of universal wave and decimal concepts, may be shown in a number of ways as shown in I-IV in Table Z.

Increase or Decrease of Magnitudes

Although the sum total of magnitudes of the two dimensions at the equipotential states total 10, the cumulative magnitude of units at the biggest surface becomes the sum total of the numerical digits for the derived dimension as the magnitude of configuration grows progressively bigger. In the case of the fundamental dimension, however, the direction is opposite. We are considering the increase in size of magnitude in the configuration. In this, the cumulative total of magnitude up to any state in the evolved configuration would be obtained by adding the magnitudes of units of the same dimension. Assuming that there would be no variation in the magnitude of unit (say of the derived dimension) from the one surface state to another, increase in magnitude up to a state could be cumulative total of the magnitudes of units at the various states. In other words, the increase of magnitude by addition involves magnitudes of units of the same dimension

and no variation in magnitude of units at the various states in the direction of increase. If there is no variation of the magnitude of unit in the direction of increase the total magnitude up to any state could be the sum total of magnitudes of units up to that state. This is shown in Table Z.

When the magnitude of unit would vary progressively in the direction of increase of magnitude, its numerical presentation in the spherical wave may be seen in II, III and IV. There should be many other modes of presentation, showing the progressive increasing magnitude of units of the dimension from state to state. In IV the wave started with the magnitude of 10 as one unit for state A but progressively 10 has passed through 10, 20, 30, 40..... to 100 or 10^2 which is the magnitude of unit at the state B. Similarly, in the state C the wave starting with 100 at B passing through 200, 300, 400 completes 1000 at state C and so on. The magnitude of unit in IV is signified by the placement of unit digit followed by zeros—one place to the left from one state to another progressively. If we take magnitude of one unit at B relative to one unit at A state in IV, the digit 1 will have position of one towards the left in the C state. The magnitude of unit digit will

have its place by one position on the left relative to B. If we add one unit digit at A and unit digit belonging to B state, taking note of the displacement and the magnitude of units for these two states, the sum total is 110. Similarly, the cumulative magnitude of units for all the states would be 1111111110. In this process, it may be noted that to get the sum total of digits belonging to the nine different states the first requirement is to convert unit digits into the magnitude of units on the common basis of the state having the least magnitude of unit as 10. The conversion of the digits of a number to a common base of least magnitude of units, followed by addition of those by properly placing the digits of the converted numbers in correct relative positions, gives the total magnitude by process of multiplication.

Decrease of Magnitude

Similarly, the direction of decrease of magnitude (numbers) is the result of cumulative reduction from a given magnitude in a direction in which magnitude of the unit either may remain constant or progressively decrease in its own magnitude. The increase or decrease of magnitude of the derived or the fundamental dimension in the respective directions in the spherical wave would also clarify the significance of what has been stated in the definition of increase of magnitude by addition and decrease of magnitude by elimination.

In the process of addition, if the magnitude of unit in progressive sequence of states remains constant, the cumulative result may be expressed by one sum. If, however, the magnitudes of the unit progressively increases, to apply the process of addition, it has to be brought to one common basis in terms of magnitude of unit belonging to state of least magnitude.

Similarly, in the process of subtraction (elimination), there would be only one result or remainder obtained, in the process of cumulative subtraction (elimination of units) the magnitude of the unit remaining constant.

In the beginning the mathematicians were confronted with many issues before the elementary aspects of evolution of magnitudes in mathematics were clear, which subsequently became the basis for subsequent evolution of various concepts in various branches of mathematics and measurements of magnitudes. The first problem was to designate by numerals the varying magnitudes of units of anything or the sum total of units of anything when they are assembled. Designation of the number of units was attempted to be put down by a vertical single line indicating one, a pair of lines indicating two and so on. By this method, the magnitude of the assembled total of units, each of constant or equal magnitude

of the same thing, could have been accomplished or signified by putting down number of vertical lines equal to the number of its units. In conception, the number of vertical lines and the corresponding number of units of things making the total is not very difficult to realise. The mode of arrangement of the vertical lines is not of great consequence. But when a cumulative sum of things of unequal magnitudes of units have to be expressed in terms of magnitudes of one common unit only, the difficulties of designation arise. For different things, their units cannot just be expressed by identical vertical lines. This confrontation went on for probably decades or centuries until the concept of tetrahedral evolution was established and the concept of increase or decrease of magnitude was understood from the concept of tetrahedral evolutionary configuration as wave of repetitive nature. A satisfactory solution had to be found for expressing the magnitudes of individual units as well as the magnitudes of total involving the association of magnitudes of the same or different things in terms of something common as least magnitude of unit. The magnitude of common unit had to be such that in terms of this least magnitude either cumulative total magnitudes of the same or different things could be satisfactorily expressed and calculated or from a cumulative total magnitude of the same or different things and their resultant magnitudes could be calculated.

The direction of increase or decrease of magnitudes by cumulative total of units of the same dimension can involve two processes: the increase of magnitude by cumulative addition of the least magnitude of units of the same thing, to arrive at the cumulative total increased magnitude, can involve the least magnitude of unit as constant common factor of least magnitude; the least magnitude of unit may also increase in the direction of increasing magnitude of total simultaneously, (as in the case of different equipotential states in the configuration of the universal spherical wave). Calculation of the total increased magnitude in the latter process would require the effect of variation of the magnitude of unit itself at various progressive states to be incorporated in the calculation. Thus in the direction of increase of magnitude of things by cumulative addition of least magnitude of unit, which undergoes increase in magnitude of its own as the total magnitude increases, the total magnitude would increase by acceleration.

Similarly decrease of magnitude of a cumulative total can occur due to progressive elimination of units of highest or least magnitudes of units from the total while, during the process of decrease of the original magnitude, the least or highest magnitudes of unit may

remain constant in the direction of decrease of magnitudes of total. In the other case, the accelerated decrease of magnitude of total would result if, during progressive elimination the least magnitude of units itself increases or the highest magnitude of units itself decreases progressively in the direction of decrease of the resulting total magnitude. The ultimate result may be the same as nil but in the two cases there may be two opposite directions: one towards the centre and the other towards the boundary of the spherical wave.

In the direction of increase of magnitude, if the process is associated with increasing variation of the magnitude the unit started with from the initial state of the process may involve simultaneous multiplication and addition of the magnitudes of the units.

Similarly, in the direction of decrease of magnitude from the state of highest magnitude of assembled total, the magnitude of total could undergo accelerated decrease if the unit simultaneously decreases in its own magnitude. The process could involve division and elimination.

The above should be of immense significance in determining the nature of configuration of the spherical wave when the magnitudes of size of configurations as well as the magnitudes of intensities of fundamental and derived dimensions viz. Energy/Matter Space/Time would be taken into account. For example, from the centre to the boundary of the wave, the tetrahedron can increase in one direction adding same magnitude of units of tetrahedron face to face and thus getting increased in magnitude of configuration in one direction. If the tetrahedron, however, expands, from the centre in 4 directions and describes expanding configurations of space with progressive increase of radius so that while the magnitude of the tetrahedron increases, at each stage with its size of total configuration, it may develop accelerated increase of total configuration in 4 directions from the centre through 4 faces. The resultant configurations in different cases, in one or more directions would be different.

Difference Between the Sum-total of the Magnitudes of Dimensions in the light of the Spherical Wave

The configuration of the spherical wave shows that the difference between the magnitudes of dimensions at a steady state in the universal spherical wave is applicable to two different and opposite dimensions at one equipotential state of the spherical wave. The different combinations of magnitudes of energy and matter at the various states in the spherical wave, including the centre and boundary, have been shown before. For

example, at the various equipotential states, the difference between the magnitudes of fundamental and derived could be written as:

(—) Infinity, —8,	(Nil), +2, +4,	Infinity as +10.
—6, —4, —2,	+6, +8 (+)	
as —10.	equality	Centre
boundary	equilibrium	

(The finite digits upto 9 along with +8 or infinity as written in the above are only relative; they should not be literally taken as exact magnitudes.) The difference between the finite digits at any state within the finite nine states in the universal spherical wave can only be finite eight. The equality equilibrium from the above would show some apparent contradiction. Here, the difference between the two 5s literally has to be nil. But the two 5s are opposites. In the universal spherical wave, the tetrahedral positions describe the various spherical surfaces by their orbital variations. The 4 positions while in motion, strictly speaking, do not simultaneously occupy the same position all at one time. Their motion in orbit is characterised by sequence i.e. by the intervals between one and the other by *orbital distance of time* in the configuration. Therefore actually no two positions, in the strictest sense, are identical even at the equality equilibrium which, in the finite sense, has been described as the surface of simultaneity of presence of positions at any instant while describing the spherical surface. Therefore no two positions will be absolutely identical and they will differ in their properties, however small that difference may be; this difference at the equality equilibrium would be *least* in the finite sense.

'Finite Zero' would mean least magnitude of difference which must be differentiated from the concept of content of nil magnitude. If the zero would refer to the magnitude of dimensions at the centre or at the boundary, while applying the significance of finite zero, however, in mathematics the significance or nil should be taken into account.

The applicability of the finite highest magnitude for the term 'infinity' is similarly applicable in the finite universal spherical wave. The difference between the two can be of any magnitude, however low, or high that may be but the former can be least but not nil and the latter finite highest but not infinity. While considering the difference of magnitudes between the various states in the universal spherical wave, one must take into account the exact nature of the two things between which the difference in their magnitudes is intended to be calculated. There are 9 finite states in the universal spherical wave between the centre and the boundary;

there is difference in the magnitudes of the same dimension situated at the various states. Then two different dimensions situated at one state also differs in their magnitudes. Therefore, the difference can be between the magnitudes of 2 different constituents at the same state and there can be difference of magnitudes of the same belonging to different states.

Absolute Significance of the terms: 'identical', 'opposite' and 'different'.

Two things are said to be identical, it is not possible to differentiate between them in any way with respect to any property relative to those two and when there is absolutely no difference between the two. Now suppose between the two things some infinitesimal magnitude of non-identity has been found in some characteristics. That introduces element of difference of least magnitude between the two things. Suppose further that some more difference also are observed between the two things the magnitude of difference between the two increases. If the two things possess properties which are infinitely (entirely) different from each other, then in that condition the two things are perfect opposites. The degree of identity or oppositeness in terms of magnitudes is determined by the magnitude of difference between the two. Two things must have certain associated magnitude of identity and also certain magnitudes of oppositeness or dis-similarity. When the magnitude of difference between the two becomes infinity the two are opposites. The magnitude of the word 'different' has two limits: on the one extreme identical where the difference is nil and the other extreme is opposite where the magnitude of difference is infinity. In between these two limits things occur in combination with characteristics of difference and characteristics of similarity between two things.

Magnitude of Zero and Infinity as difference between the magnitudes of two dimensions in the light of the Spherical Wave.

In the universal spherical wave, at the equality equilibrium surface, when the magnitudes of all the four dimensions assume equality the difference between the magnitudes of various dimensions apparently tend to become nil. The magnitude of variability or its intensity associated with the dimensions tend to assume magnitude of infinity. Since the magnitudes of infinity or nil is not permissible in the finite concept, i.e. in the finite configuration of the spherical wave, the difference between the magnitude of dimensions at the equality equilibrium

is not nil but it would be infinitely small and thus greater than nil. There should remain some difference, however small that may be and the difference should be finite least even at equality equilibrium surface. Similarly the difference between any two dimensions anywhere within the finite wave cannot also be of infinite magnitude. The difference could only be finite highest, and in any case it must not be infinity. The infinite difference between the two dimensions can only be beyond the finite universal wave either towards the centre or to the boundary; if the difference at the centre is positive infinity, at the boundary it is negative infinity.

It should be appreciated that, in the spherical wave, when the magnitudes of difference between any two dimensions are spoken of, it is the difference between two opposites, viz. magnitude of fundamental and magnitude of derived, either in one phase or in two phases.

Mathematics of Zero and Infinity

In the configuration of the universal spherical wave, in respect of magnitudes of dimensions which make the wave, the term 'Zero' signifying nil (not least finite but containing nothing that is of nil magnitude of the dimensions) has only two states of association viz. the centre and the boundary—the central point containing nil magnitude of derived dimension and the boundary spherical surface where the intensity of fundamental dimension is nil. As far as the finite evolutionary wave is concerned, the centre is the preceding state which is beyond comprehension relative to the finite wave; so also the boundary which also is incomprehensible relative to the finite wave.

Similarly, for the term infinity, the centre is the state of infinite magnitude intensity of fundamental dimension the boundary is the infinite magnitude intensity of derived dimension. In the finite wave, magnitudes of infinity or nil are not relevant.

These facts about the magnitudes of dimension as infinity or zero implying nil should provide correct guidance as to the permissible nature of combinations of numerals representing magnitudes of dimensions in association and the magnitudes of numbers would be governed accordingly.

In the background of the above premises let us examine the various mathematical operations involving zero and infinity. When zero means nil, it refers to magnitude of a dimension when it can only be in combination and equilibrium with another opposite dimension whose

magnitude is infinity. Combination of nil and infinity with any finite magnitudes or numbers is not feasible in the finite universal spherical wave.

Thus if zero is added to a number, there is no change of the number. This is obvious either at the centre or at the boundary where only one dimension, in its infinite state, exists where anything else in association would have no magnitude and must be nil. Therefore, addition or subtraction of nil from the infinity of the fundamental at the centre or the infinity of the derived at the boundary or the finite magnitudes of both would not change those magnitudes.

It should be noted that these two infinities at the centre and the boundary refer to two opposite dimensions viz. fundamental and derived at which if one is infinity, the other is nil and vice versa. Therefore, the magnitude of infinity has two directions between nil and infinity; one may be positive direction from the boundary towards the centre and the other negative direction from centre to the boundary. In these two states, similarly, if zero would be multiplied by infinity, the process can only be imaginary; the nil would remain the same; similarly, also if infinity would be multiplied by nil—capacity remains the same and no multiplication occurs at the state of imaginary zero. Similarly when zero is multiplied by anything finite, which means the same thing as nil added some finite number of times, whatever the magnitude of finite number of times of nil be the result would always be nil. On the other hand, if some magnitude of one would be added to infinite magnitude of another, the approach to get the result would be two-fold. Either the first would have to increase in its own magnitude to rise up to the level of magnitude of infinity in opposite direction so that the result would be one of difference between (+) infinity and (−) infinity which again becomes an infinity configuration as would be evident from the spherical wave difference between the centre and the boundary. The other approach would be that the finite magnitude must reduce its own potential to nil to be added to infinity which also is infinity. Thus, anything finite, which when added to infinite magnitude of another, would result in magnitude of infinity, both ending up in magnitudes which are not finite and incomprehensible.

Let us now consider the nature of the function zero divided by zero and its significance at the centre and at the boundary. Zero of the two opposite dimensions at the centre has nil magnitude of intensity of the derived dimension. At the boundary, zero divided by zero would mean nil magnitude of zero of configuration of

the derived divided by nil magnitude of intensity of the fundamental. Similarly, the ratio infinity at the centre would refer to intensity of fundamental dimension divided by infinite size of imaginary configuration of derived dimension. At the boundary it would refer to infinite magnitude of intensity of the derived dimension divided by the infinite magnitude of size of the configuration of the fundamental dimension. All these combinations, being at the centre and the boundary states relative to the finite spherical wave, are imaginary or abstract states as far as the finite wave is concerned.

Reference in this connection may be made to “History of Hindu Mathematics” by B. B. Dutta and A. N. Singh which is considered as the source book in this direction. This book, which describes the background of development of mathematics in Ancient India from available resources and works, will leave no doubt as to how the evolution of various mathematical concepts were developed: arithmetic as Patiganit and Algebra as Bijganit in ancient India. All the deductions therein had at the very root the concepts and postulates of tetrahedral evolutionary wave. In fact in ancient India various postulates in science, geometry, trigonometry, mathematics, astronomy, astrology and various philosophies had their roots starting from and following up the concept of tetrahedral evolutionary wave with its various associated significances.

Explanation of the two propositions

$$\begin{aligned} 0/\text{anything} &= 0 \\ \text{anything}/0 &= \text{infinity} \end{aligned}$$

In the first case zero means nil. To divide nil or nothing into parts means also nil magnitude of imaginary parts; since, if there is something, however least that may be, it can be conceived of as being divisible. The number of parts would also in the latter case be least but not nil, whereas when there is nothing, no parts can be made thereof; the results of division would be of nil magnitude. Taking the second case, i.e. if anything is divided by zero, the answer would be infinity. The explanation of this is that in the combination of two as numerator and denominator in the theory of spherical wave, they must be opposites. The combination of any magnitude as numerator and magnitude of zero meaning nil as denominator is only possible in combination when the numerator assumes infinity.

The same explanation also could have been offered in the first case in which the result would have been 0/Infinity. This would apply only to the boundary state,

if the direction of magnitudes would be towards fundamental dimension at the centre when the numerical magnitudes are relative to magnitude of fundamental in the positive direction towards the centre. Zero relative to intensity of fundamental would be to the boundary when its magnitude is nil. In the same way, something/0 is infinity would be the position at the centre where something must become of infinite intensity.

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The opinions expressed by the authors are their own and do not necessarily reflect the views of the Planning and Development Division of the Fertilizer Corporation of India Ltd.



Fig. 1
Charging of Catalysts in a
High Pressure CO-conver-
sion Plant of the Sindri
Fertilizer Factory.

CO-Conversion Catalyst

The water-gas shift reaction is of great importance in the chemical industry—a basic step in the manufacture of fertilizers, methanol and other chemicals. The catalysts employed in the industry for the above reaction are of iron oxide-chromium oxide type. The activity of the catalyst depends on the methods of preparation.

The Planning and Development Division has developed its own know-how and established production of a series of catalysts for use in CO-conversion with indigenous raw materials and indigenous equipment. Since 1954, Sindri Fertilizer Works are using the indigenous atmospheric pressure CO-conversion catalyst developed and produced by this Division.

In 1965 one of the two streams of the Gas Reforming Plant at Sindri was charged with medium pressure CO-conversion catalyst developed in this Division, and from April 1966, both the

streams are operating entirely with indigenous medium pressure catalysts.

Using this Division's medium pressure catalyst, CO-concentration at the exit has been lowered by more than 1 per cent operating at a temperature lower by 50°C than in the case of the imported catalyst. This has resulted in an increase in hydrogen availability equivalent to 2 tonnes per day of ammonia at the present rate of production. It is expected that with higher rate of production in the gas reforming plant, increase in ammonia production will be correspondingly more. Fig. 1 shows one of the CO-conversion units in Sindri Fertilizer Works being charged with CDC-66 catalyst, developed in this Division.

A low pressure CO-conversion catalyst having been developed, work on its plant scale application under plant conditions is in hand.



Fig. 2
Cylindrical Pellets of Me-
dium Pressure CO-conver-
sion Catalyst.

Physical Studies on Coprecipitated Oxides

Part I: Al_2O_3 — Fe_2O_3 System

By

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The role of iron oxide in the coprecipitated binary Al_2O_3 — Fe_2O_3 system has been studied in relation to the nature of transformed product with the aid of x-ray and DTA techniques. It has been observed that the transformation temperature of this coprecipitated system to γ - Al_2O_3 and then to α - Al_2O_3 is influenced considerably by the presence of ferric oxide. The variation of their transformation temperature has been accounted for the substitution of Fe^{3+} in the respective Al_2O_3 lattice. The crystallite size of γ - Al_2O_3 formed at 450°C has also been presented.

Introduction

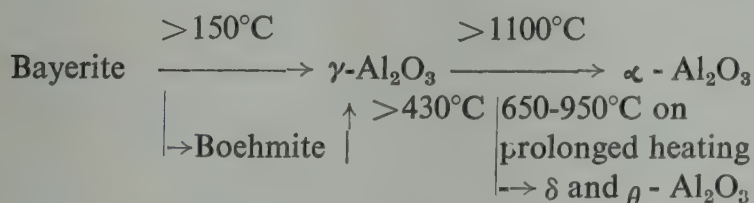
It is well-known that catalysts with binary composition Al_2O_3 - Fe_2O_3 are used extensively for many industrial reactions. The system having low ferric oxide content is effectively employed for the dehydration of alcohols and their codehydration with ammonia and amines, hydrolysis of esters and conversion of CO with steam. But very little is known about the state of aggregation of the phases obtained by thermal treatment of this system where the percentage of ferric oxide is not very high—well below 15 mol. per cent.

When aluminium hydroxide is precipitated from soluble aluminium salts by an alkali, different varieties of aluminium hydroxide are formed under different conditions. On precipitation with ammonium hydroxide in cold from a mixture of aluminium and iron nitrates, bayerite is formed¹, which on heating undergoes several phase changes as follows²:

γ - Al_2O_3 formed from bayerite and boehmite is catalytically active³. In fact, coprecipitated Al_2O_3 - Fe_2O_3 samples are preheated to about 400°C before using as catalyst. Usually the crystal size of γ - Al_2O_3 at 400 - 450°C resulting from pure bayerite has been found to be very small, and it is reported³ that there is a direct relation between the catalytic activity and the crystal size of this γ - Al_2O_3 . In the background of binary Al_2O_3 - Fe_2O_3 system, it is worthwhile to mention the structural characteristics of some of the oxides of aluminium and iron which are comparable to each other. (Table below):

As such, it is quite expected that the solid solution of Al_2O_3 - Fe_2O_3 may be formed on heating bayerite containing coprecipitated iron hydroxides. In fact, formation of saturated solid solution of γ - and α - Al_2O_3 with 8 and 11 mol. per cent of ferric oxide respectively has been reported in the literature⁴.

In the present investigation, attempts have therefore been made to elucidate the state of aggregation of Al_2O_3 - Fe_2O_3 system with varying amount of ferric oxide, viz. from 0 - 15 mol. per cent, with particular reference to the state of aggregation of phases which are formed by thermal treatment.



Crystal System	Name	Structural Cell dimensions (Å)	Name	Structural Cell dimensions (Å)
Cubic	γ - Al_2O_3	$a = 7.89\text{--}7.90$	γ - Fe_2O_3	$a = 8.34$
Hexagonal	α - Al_2O_3	$a = 4.76$ $c = 13.00$	α - Fe_2O_3	$a = 5.028$ $c = 13.74$

Experimental

The alumina-ferric oxide samples with 0.5, 1.0, 3.0, 5.0, 8.0 and 15.0 mol. per cent of ferric oxide were prepared in the laboratory by coprecipitation of aluminium and iron hydroxides from 0.1 N. solution of their nitrate and chloride respectively with 10 per cent ammonia solution at a room temperature of about 26°C maintaining pH at 10. Pure aluminium hydroxide was prepared under identical conditions. All the reagents used were of A.R. quality. The samples were washed thoroughly with distilled water 6 to 7 times for removing the traces of chloride ion which was tested with silver nitrate solution. The samples were dried in air oven at 80°C. The x-ray photographs of the samples collected from sample holder of DTA apparatus at temperatures such as 450 and 1210°C were taken by using FeK α radiation in the Philips x-ray unit of model PW 1010 at 30 KV, 10 mA with a Debye-Scherrer camera of 5.73 diam. The interplaner spacings of each sample were measured in the usual way from the lines of the corresponding Debye-Scherrer photographs assessing their relative intensity visually. The size of the crystallites of those samples heated to 450°C was found out from the broadening of the line corresponding to 1.398 Å of γ -Al₂O₃ in their powder photographs using the modified Scherrer equation⁵ which gives an idea about the size of the crystallites.

$$\text{Crystallite size } (D_{hkl}) = \frac{0.9 \lambda}{\beta_{\frac{1}{2}} \cos \theta}, \text{ where}$$

$\beta_{\frac{1}{2}}$ = The half maximum line breadth=B-b

B = Experimentally observed half maximum breadth of diffraction line of the test sample.

b = Half maximum breadth of a line produced under similar geometrical conditions by quartz sample with crystallite size well in excess of 1000 Å.

λ = Wave length of the x-radiation.

θ = Bragg angle of the diffraction line of the test sample.

The lattice parameter of α -Al₂O₃ present in the coprecipitated samples heated at 1210°C was found out according to the method described by Henry, Lipson and Wooster⁶. For this purpose, a Debye-Scherrer camera of 11.46 cm diameter was used. In this method, the values for cell edge (*a*) calculated from the spacings of high angle lines were plotted against the function $1/2$

$$\left(\frac{\cos^2 \theta}{\sin \theta} + \frac{\cos^2 \theta}{\theta} \right) \theta \text{ being the Bragg angle, and the}$$

resulting straight line obtained was extrapolated for the accurate value of cell edge (*a*₀) where the value of the above function tends to be zero.

DTA investigation of the samples was performed by a fully automatic DTA apparatus of Linseis model in the temperature range 26-1300°C. Pt/Pt-Rh thermocouple was used for this purpose. Sample holder was made of thin platinum sheet. The reference substance used was ignited aluminium-oxide. The rate of rise of temperature was 10°C/min.

Results

DTA diagrams of the oven-dried samples are shown in Fig. 1.

X-ray diffraction data of the samples heated to different temperatures are shown in Tables 1 and 2 (A & B) and their patterns in Figs. 2 and 3. Variation of crystal size of γ -Al₂O₃ with Fe₂O₃ content of the samples are shown in Fig. 4. Lattice parameter of α -Al₂O₃ is given in Table 3. The peak temperatures of the samples were plotted against their ferric oxide content (Fig. 5).

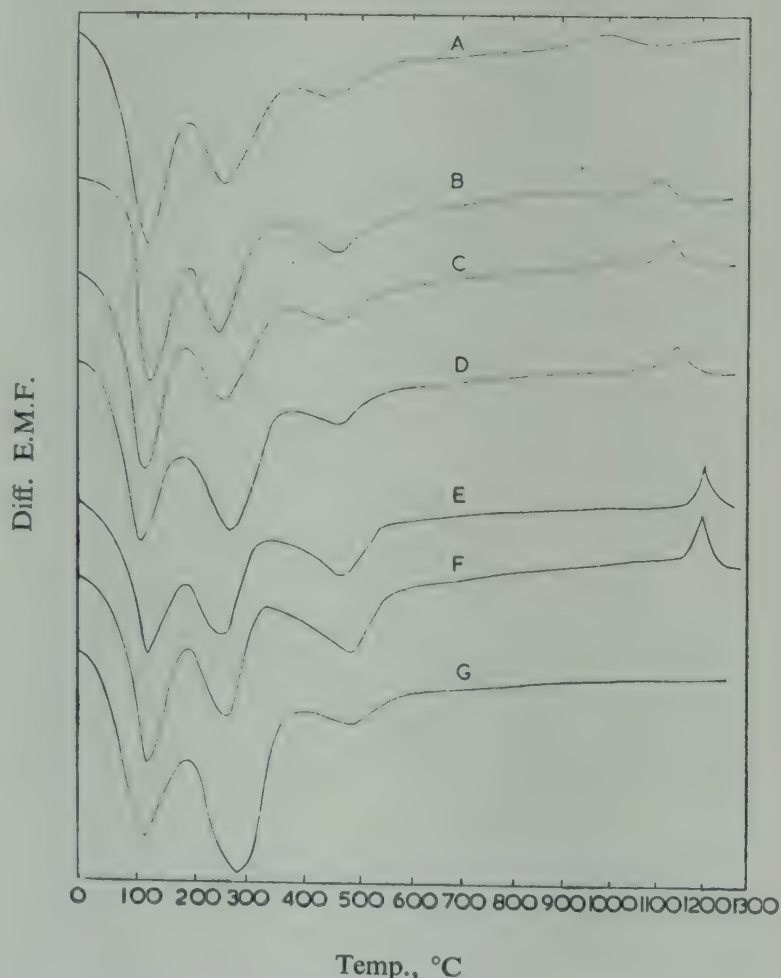


Fig. 1—DTA Thermograms of Coprecipitated Al₂O₃ - Fe₂O₃ System

A to G: Samples containing 15, 8, 5, 3, 1, 0.5 and 0.0 mol per cent of Fe₂O₃ respectively.

TABLE 1—X-RAY DATA OF $Al_2O_3-Fe_2O_3$ SYSTEM HEATED TO 450°C
(FeK α radiation, 30 kv, 10 mA, 4 hours' exposure)

$Al_2O_3 : Fe_2O_3$ (100 : 0)		$Al_2O_3 : Fe_2O_3$ (99 : 1)		$Al_2O_3 : Fe_2O_3$ (95 : 5)		$Al_2O_3 : Fe_2O_3$ (92 : 8)		$Al_2O_3 : Fe_2O_3$ (85 : 15)		$\gamma-Al_2O_3$ (Standard)		Boehmite (Standard)	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
6.04	vw	6.20	vw	6.19	vw	—	—	—	—	—	—	6.11	100
4.543	vw	—	—	4.563	vw	4.631	vw	—	—	4.55	10	3.16	65
2.374	w	2.365	w	2.381	w	2.397	w	2.405	w	2.387	35	2.35	53
2.296	w	2.296	vw	2.296	w	2.310	vw	2.310	vw	2.283	20	—	—
1.970	s	1.970	s	1.970	s	1.984	s	1.985	s	1.997	100	—	—
1.395	m	1.393	m	1.393	m	1.402	m	1.408	m	1.398	90	—	—

vs=very strong, s=strong, m=medium, w=weak, vw=very weak, I=relative intensity, d=interplaner spacing.

TABLE 2A—X-RAY DATA OF $Al_2O_3-Fe_2O_3$ SYSTEM HEATED UP TO 1210°C
(FeK α radiation, 30 kv, 10 mA, 4 hours' exposure)

$Al_2O_3 : Fe_2O_3$ (99.5 : 0.5)		$Al_2O_3 : Fe_2O_3$ (99 : 1)		$Al_2O_3 : Fe_2O_3$ (97 : 3)		$Al_2O_3 : Fe_2O_3$ (95 : 5)		$Al_2O_3 : Fe_2O_3$ (92 : 8)		$Al_2O_3 : Fe_2O_3$ (85 : 15)		$\alpha-Al_2O_3$ (Standard)		$\alpha-Fe_2O_3$ (Standard)	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
3.538	w	3.54	w	3.516	w	3.494	w	3.480	w	3.494	w	3.48	60	2.69	100
										2.673	w				
2.586	m	2.586	m	2.580	m	2.584	m	2.553	m	2.575	m	2.55	85		
										2.505	vw			2.514	75
2.416	w	2.420	w	2.411	w	2.406	w	2.386	w	2.406	w	2.380	32	1.692	45
2.336	vw	2.327	vw									2.66	1		
2.119	s	2.112	s	2.112	s	2.109	s	2.092	s	2.112	s	2.085	100		
1.765	m	1.760	m	1.762	m	1.760	m	1.766	m	1.765	m	1.741	45	1.484	20
										1.688	vw				
1.625	vs	1.621	vs	1.625	vs	1.621	vs	1.606	vs	1.605	vs	1.601	85		
		1.566	vw									1.546	2	1.452	25
1.534	vw	1.532	w	1.532	w	1.531	vw	1.516	vw	1.533	vw	1.511	8		
										1.485	vw				
										1.452	vw				
1.423	m	1.419	m	1.423	s	1.421	m	1.410	m	1.424	m	1.405	35		
1.390	s	1.388	s	1.390	s	1.389	s	1.379	s	1.392	s	1.374	50		
1.252	m	1.249	m	1.25	w	1.250	m	1.241	m	1.252	m	1.238	15		
1.201	w	1.199	m	1.200	w	1.200	w	1.193	w	1.204	vw	1.190	5		
1.157	vw	1.158	vw	1.157	vw	1.157	vw	1.150	vw	1.159	vw	1.148	5		
1.134	vw	1.133	w	1.135	vw	1.134	w	1.128	w	1.139	vw	1.123	7		
1.108	w	1.107	w	1.109	vw	1.108	w	1.103	w	1.111	w	1.099	8		
1.087	w	1.085	w	1.087	w	1.087	w	1.082	w	1.089	m	1.079	9		
1.050	m	1.049	m	1.05	w	1.05	m	1.046	m	1.053	m	1.043	15		
1.023	vw	1.024	vw	1.024	vw	1.025	vw	—	—	1.027	vw	1.017	3		
1.002	m	1.003	m	1.003	m	1.004	m	1.002	m	1.007	m	0.997	10		

VS=very strong, S=strong, M=medium, W=weak, VW=very weak, VVW=very very weak.

TABLE 2B—X-RAY DATA OF PURE PRECIPITATED Al_2O_3 HEATED UPTO 1210°C
 $\text{FeK } \alpha$ radiation, 30 kv, 10 mA, 4 hours' exposure)

Precipitated Al_2O_3 , 100%		Standard Data of Al_2O_3 Phases					
		Phase θ		Phase γ		Phase α	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
4.555	vw	4.53	30	4.55	10		
3.475	m	—	—	—	—	3.48	60
2.846	m	2.84	80	—	—	—	—
2.731	m	2.72	100	—	—	—	—
2.555	s	2.564	20	—	—	2.55	85
2.450	s	2.439	90	—	—	—	—
2.386	vw	—	—	2.387	35	2.380	32
2.321	w	2.314	60	—	—	—	—
2.261	w	2.254	50	2.283	20	—	—
2.089	s	—	—	—	—	2.085	100
2.020	m	2.018	60	—	—	—	—
1.959	w	1.955	15	1.977	100	—	—
1.915	m	1.907	35	—	—	—	—
1.801	vw	1.801	15	—	—	—	—
1.764	vw	1.773	7	—	—	—	—
1.739	s	—	—	—	—	1.741	45
1.601	s	—	—	—	—	1.601	85
1.541	m	1.542	30	—	—	1.546	2
1.510	w	1.510	8	1.521	10	1.511	8
1.480	w	1.486	20	—	—	—	—
1.450	m	1.453	30	—	—	—	—
1.422	vw	1.426	15	—	—	—	—
1.401	s	1.404	40	—	—	1.405	35
1.385	vs	1.388	90	1.398	90	—	—
1.369	s	—	—	—	—	1.374	50
1.292	vw	1.295	10	—	—	—	—
1.274	vw	1.285	10	—	—	—	—
1.252	vw	1.259	6	—	—	1.238	15
1.230	m	1.233	5	—	—	1.234	10

TABLE 3—LATTICE PARAMETER OF α - Al_2O_3 OBTAINED
AT 1210°C BY HEATING COPRECIPITATED
 Al_2O_3 - Fe_2O_3 SAMPLES

Sample $\text{Al}_2\text{O}_3 : \text{Fe}_2\text{O}_3$ in mol. ratio	Lattice Parameter* (a_0) of Al_2O_3 (Å)
100:0	4.760
99.5:0.5	—
99:1	4.761
97:3	4.766
95:5	4.768
92:8	4.774
85:15	4.791

*Lattice parameter determined after correcting absorption and divergence of X-ray beam, axial non-coincidence of camera and specimen, film shrinkage, etc.

Discussion

DTA study of the oven-dried coprecipitated samples as well as precipitated Al_2O_3 (vide Fig. 1) reveals the presence of bayerite and boehmite in each case. The formation of boehmite may be attributed to the partial dehydration of bayerite at 80°C which is the initial drying temperature.

Again, DTA curves of samples containing iron are similar to that of pure precipitated aluminium oxide sample except one exothermic peak which appears in the region of $1000 - 1205^\circ\text{C}$ (Fig. 1) in case of coprecipitated samples. The endothermic peaks which are common in both the cases appear in the temperature region of $110 - 120^\circ$, $250 - 280^\circ$ and $450 - 480^\circ\text{C}$. The first endothermic peak in their DTA diagrams represents loss of mechanically bound moisture from

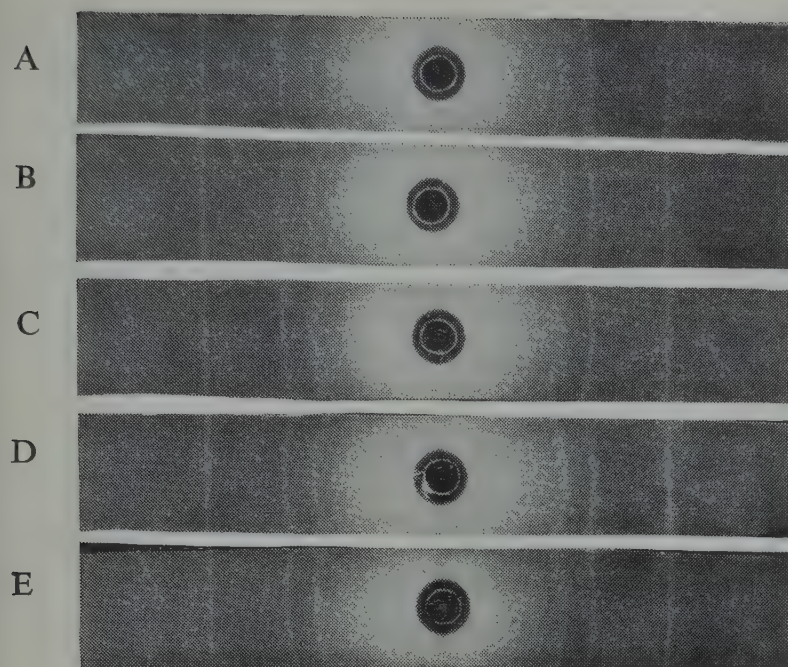


Fig. 2—X-ray Diffraction Pattern of $\text{Al}_2\text{O}_3 : \text{Fe}_2\text{O}_3$
Heated to 450°C .

A to E Samples Containing 0, 1, 5, 8 and 15
mol. per cent of Fe_2O_3 respectively

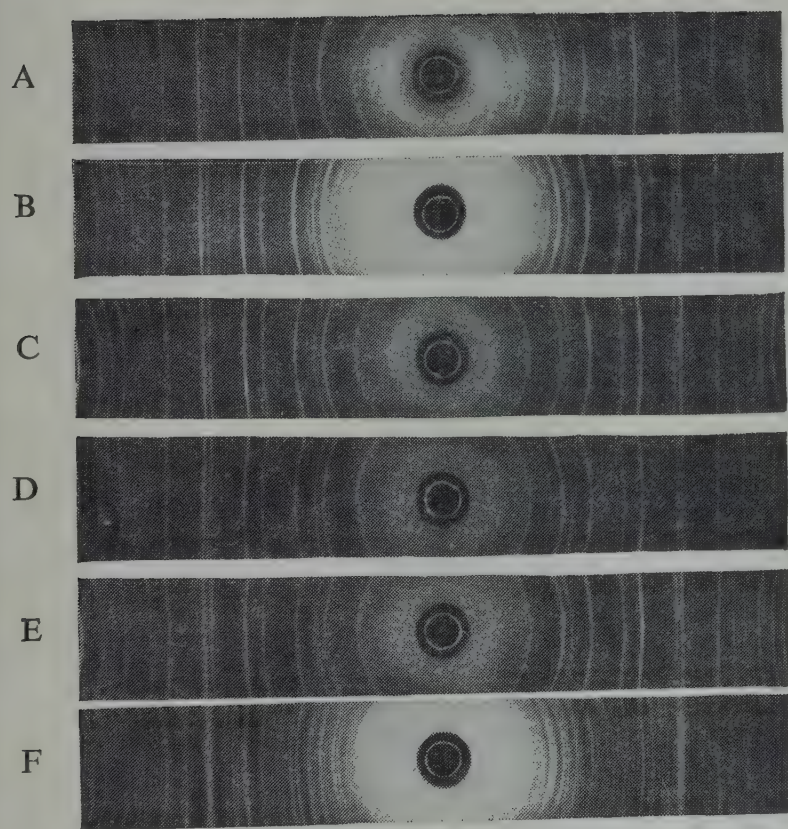
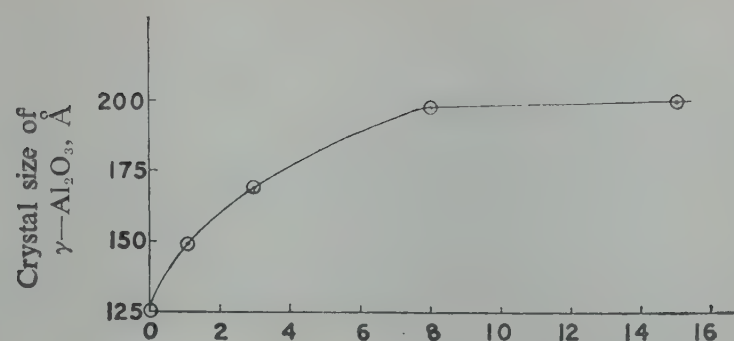


Fig. 3—X-Ray Diffraction Pattern of $\text{Al}_2\text{O}_3 : \text{Fe}_2\text{O}_3$
Samples Heated to 1210°C .

A to F Samples Containing 0.5, 1, 3, 5,
15 and 0.0 mol. per cent of Fe_2O_3 respectively



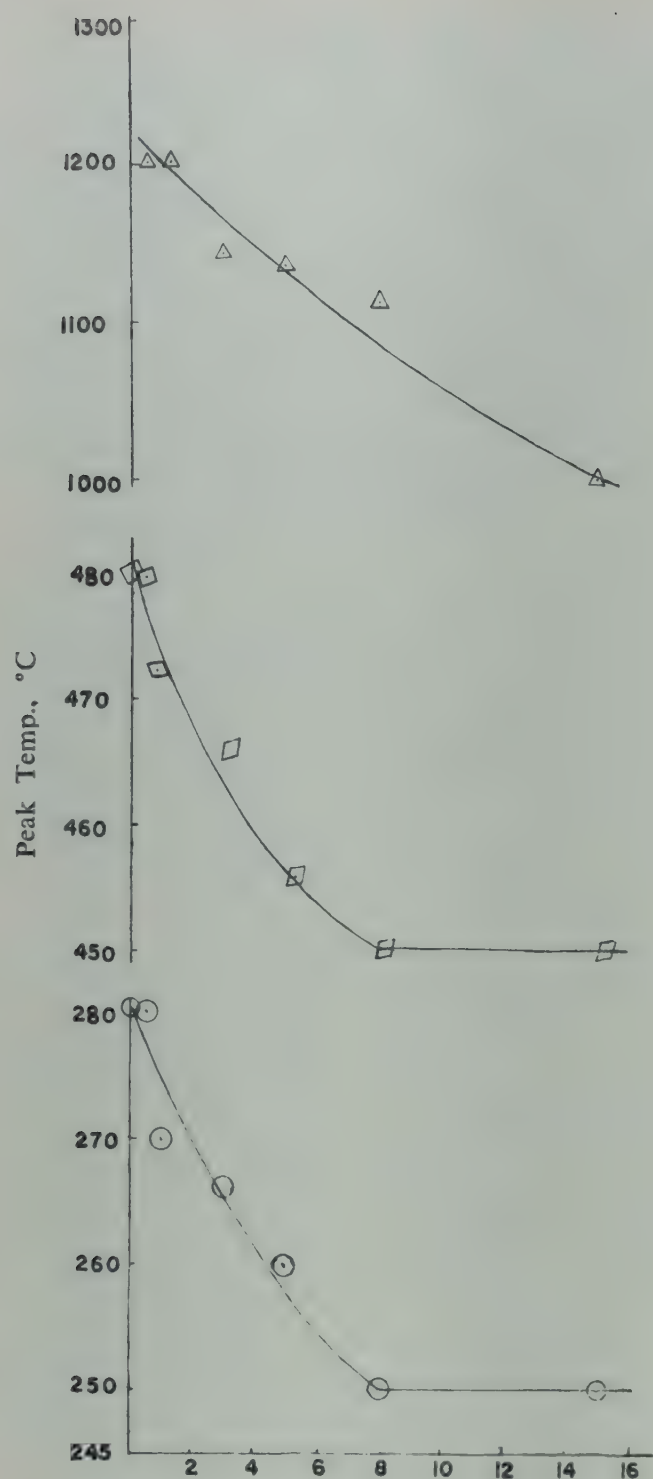
Fe_2O_3 in Coprecipitated $\text{Al}_2\text{O}_3 - \text{Fe}_2\text{O}_3$ System, mol. %

Fig. 4—Variation of Crystal Size of $\gamma\text{-Al}_2\text{O}_3$
with Fe_2O_3 Content in Coprecipitated
 $\text{Al}_2\text{O}_3 - \text{Fe}_2\text{O}_3$ System

the sample whereas the second and third ones correspond to the formation of $\gamma\text{-Al}_2\text{O}_3$ from bayerite and boehmite respectively². The x-ray data of heat treated sample at 450°C (heated in DTA sample holder) reveal the presence of $\gamma\text{-Al}_2\text{O}_3$ as a bulk phase in each case. Besides $\gamma\text{-Al}_2\text{O}_3$, a very small amount of boehmite has also been found in samples containing up to 5 mol. per cent Fe_2O_3 (Fig. 2 and Table 1).

Again the temperature of the peaks due to formation of $\gamma\text{-Al}_2\text{O}_3$ decreases with increase of ferric oxide content of the samples up to 8 mol. per cent, beyond which it is constant (Fig. 5). This indicates that the presence of iron in coprecipitated samples up to 8 mol. per cent has a distinct influence on their transformation to $\gamma\text{-Al}_2\text{O}_3$. Lowering of these peak temperatures may be due to a gradual incorporation of Fe^{3+} ion in $\gamma\text{-Al}_2\text{O}_3$ lattice till a saturated solid solution with 8 mol. per cent ferric oxide is formed. The crystal size of this $\gamma\text{-Al}_2\text{O}_3$ is very fine in nature (around 125\AA to 200\AA) and increases with the increase of Fe_2O_3 content of the samples up to 8 mol per cent (Fig. 4).

Again, presence of the exothermic peak at $1000\text{--}1205^\circ\text{C}$ in coprecipitated samples indicates the transformation of these $\gamma\text{-Al}_2\text{O}_3$ to $\alpha\text{-Al}_2\text{O}_3$. X-ray data of these samples heated beyond this peak temperature (i.e. at 1210°C) reveal the presence of $\alpha\text{-Al}_2\text{O}_3$ only in samples containing up to 8 mol. per cent ferric oxide and small amounts of $\alpha\text{-Fe}_2\text{O}_3$ besides $\alpha\text{-Al}_2\text{O}_3$ in samples containing 15 mol per cent ferric oxide (Table 2A, Fig. 3). In contrast to that, x-ray data of precipitated Al_2O_3 heated to 1210°C under identical condition reveal the presence of $\theta\text{-Al}_2\text{O}_3$ along with its γ - & α - phases (Table 2B, Fig. 3). Besides, the exothermic peak temperature has also been found to decrease with increase of ferric oxide content of the



Fe₂O₃ in Coprecipitated Al₂O₃ - Fe₂O₃ System, mol %

Fig. 5—Variation of Peak Temp. with Fe₂O₃ Content of Coprecipitated Fe₂O₃ - Al₂O₃ System

coprecipitated samples (Fig. 5). All these indicate that the presence of ferric oxide in γ -Al₂O₃ has a distinct influence on the transformation of γ -Al₂O₃ to α -Al₂O₃ phase which is retarded in case of pure γ -Al₂O₃ and the sluggish nature of this transformation in the latter case helps the formation of other intermediary phases like θ -Al₂O₃. Lattice parameter of α -Al₂O₃ so formed due to this transformation has also been found to increase with the increase of Fe₂O₃ content in their bulk composition (Table 3). This indicates that the decrease of this transformation temperature is due to increasing amount of substitution of Fe³⁺ ion in α -Al₂O₃ lattice. Furthermore, presence of α -Fe₂O₃ as free phase in sample containing 15 mol per cent ferric oxide indicates that this substitution does not proceed beyond the state of saturated solid solution where the concentration of ferric oxide is 11 mol per cent.

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Selectivity and Pore Size Distribution in Active Carbon—Part I

By

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Surface areas of four samples of active carbon, calculated from their water desorption isotherm using Harvey's equation and also from B.E.T. equation using nitrogen adsorption isotherm, have shown a fairly good agreement. Total pore, micro and submicro pore volumes of all the samples were calculated from mercury, water and helium displacement values and pore size distribution was computed using Kelvin equation.

Attempts to correlate pore size distribution and other physical characteristics with the adsorption capacities of the samples with respect to hydrogen sulphide, methylene blue and iodine have been made. A comparison of the data shows that the specific surface and total pore volume do not have any relation with the specificity of the active carbon. Hydrogen sulphide retention capacity appears to depend on pores having diameter less than 10\AA . Results show that pore sizes between 12° to 30\AA are suitable for methylene blue adsorption.

Pore size distribution throws some light on the effect of activating agents and temperature of activation attributing specificity of carbon. Increase of concentration of activating agents and of temperature of activation seem to destroy submicro pores, thereby lowering hydrogen sulphide retention capacity.

Active carbon is a porous material having a strongly developed internal surface. The physical structure, the porosity and the accessibility of their internal surface to the molecules in liquid and gas phase exert fundamental influence on their specificity and selectivity. The selectivity of active carbon to a wide variety of its use, such as decolourising, vapour adsorption, solvent recovery, purification of industrial gases, catalyst carrier, etc., is associated with pore size distribution.

It is common knowledge that selective adsorption by a substance like active carbon, having a highly developed internal surface, is associated with the physical process of mass transfer in the pores, which again is dependent on the diameter of pores. Thus, for ascertaining selectivity of active carbon and interpretation of physical adsorption, a knowledge of pore size distribution is of great significance.

The present paper deals with the measurement of pore volume, surface area and pore size distribution of some active carbon samples. The object is to ascertain if any of these data can predict specificity of

active carbon for adsorption of hydrogen sulphide from industrial gases. In order to understand the selective nature, in addition to hydrogen sulphide adsorption capacity, the carbon samples were also tested for methylene blue and iodine capacities.

Experimental & Calculations

Investigations were carried out with four samples of active carbon, of which one (Sl. No. 4) was imported, while the others were prepared from S. Arcot lignite by zinc chloride activation in the trial production unit of this Division (Table 1).

(A) *Total Pore Volume*: The pore volumes of all the samples were determined from the difference of mercury and helium displacement values. The mercury displacement values were measured in an apparatus similar to one described by Juhola and Wiig¹, while those of helium displacement were determined by a modified form of the apparatus used by Kokes².

(B) *Sub-micro Pore Volume*: The values of sub-micro pore volume were obtained by the difference of displacement values of water and helium ($D_{H_2O} - D_{He}$).

TABLE 1—ACTIVITY DATA OF ACTIVE CARBON SAMPLES

Sample No.	Iodine value	Methylene Blue Adsorption	H ₂ S Adsorption	Ash, %
1. Lignite: ZnCl ₂ (1:5) prepared at 800°C	942.4	248.6	121.8	11.8
2. Lignite: ZnCl ₂ (1:1.5) 800°C	932.9	254.8	112.0	15.25
3. Lignite: ZnCl ₂ (1:1.5) 850°C	859.0	261.7	100.0	14.2
4. Active Carbon (Merck)	901.8	227.0	55.0	3.7

(C) *Surface Area*: (a) Nitrogen isotherm for all the samples was obtained in a conventional adsorption apparatus, and by applying the B.E.T. equation the surface areas were calculated. (b) Surface areas were also computed from water vapour isotherms following Harvey's method³.

(D) *Specificity of the Samples*: All the samples were tested for hydrogen sulphide, iodine and methylene blue (M.B.) adsorption capacities. Adsorption measurements were carried out according to an earlier method⁴.

(E) *Pore Size-Distribution*: The pore size distribution of all the samples was calculated from water vapour desorption isotherm by applying a modified form of Kelvin equation. The quantitative relationship between capillary radius and partial pressure of the superimposed vapour is given by the Kelvin equation as:

$$L_n P/P_0 = \frac{-2V\sigma \cos \theta}{\gamma RT} \quad \dots (1)$$

Using this equation, it is possible to calculate the average radius (r) and pore size distribution i.e. $\frac{dv}{dr}$ against ' r ' where v is volume.

Many workers do not regard this ' r ' as half the distance between two adsorbed films in the capillaries. Harvey³ has considered a monolayer formed on the capillary walls, and the rest of the liquids is condensed in pores; and on this assumption, he has deduced a formula for the calculation of surface area from capillary condensation. He has divided the total surface in a number of segments, and the areas of these segments were calculated separately and finally summed up. His formula³ is:

$$\Delta S = 4.607 (V_2 - V_1) \frac{\log r_2/r_1}{r_2 - r_1} \quad \dots (2)$$

Where ΔS is the area of all the capillaries' walls between r_2 and r_1 , and

V_2, V_1 are volumes of the adsorbates condensed including and up to radii r_2 and r_1 respectively.

Now, in view of the adsorbed layer on the walls of the capillaries, Harvey has applied correction and modified the formula³ for calculating the surface area, which comes down to this

$$S = \frac{r^2}{(r-d)^2} \times 4.607 \frac{(v_2 - v_1)}{(r_2 - r_1)} \log \frac{r_2}{r_1} \quad \dots (3)$$

whereas r is the radius of the outer cylinder and

$$r = \frac{r_2 - r_1}{2.303 \log \frac{r_2}{r_1}}$$

and d diameter of the adsorbed molecule.

The equation (3) has been utilized for calculating the surface area.

Pore size distribution of these samples were calculated assuming a bimolecular layer on the surface of the capillary walls, i.e. the actual radius (r) has been taken to be equal to $r+2d$ whereas ' d ' is the diam. of the adsorbed molecule⁵.

An all-glass apparatus was used for obtaining adsorption/desorption isotherms at various values of partial pressure of water vapour (Fig. 1). It comprises a reservoir (a) containing sulphuric acid of predetermined concentration. The reservoir through a ground glass joint and stop-cock is connected to a 13-14 mm. diam. manifold. The mercury manometer (m) is in line with this manifold connected to a rotary high vacuum pump through vacuum reservoir 'Y' and drying towers (t_1 and t_2). During experiment the acid reservoir (a) and sample capsules were all placed in a common thermostat maintained at $30^\circ \pm 0.1^\circ \text{C}$.

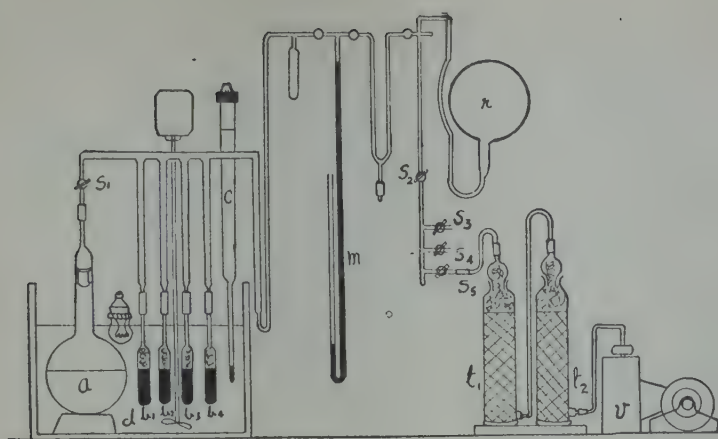


Fig. 1—Apparatus for Studying Water Vapour Isotherms

- a — H_2SO_4 —Water Mixture
- b_1, b_2, b_3, b_4 — Sample Tubes
- c — Contact Thermometer
- d — Water Bath
- m — Manometer
- r — Vacuum Reservoir
- t_1, t_2 — Calcium Chloride Towers
- v — Vacuum Pump
- S_1, S_2, S_3, S_4, S_5 — Stop Cocks

Keeping in view that presence of adsorbed impurities can greatly influence the adsorption/desorption isotherms, great care was taken in cleaning the surface of the samples by repeated flushing. Before commencing, the samples in the capsules were heated at 150°C for 6 hours at a vacuum of about 10^{-2} mm. Hg. The samples were then allowed to cool down to room temperature under the same vacuum. The manifold holding the evacuated samples was then connected with the water reservoir containing de-aerated distilled water. Adequate time was allowed to get the samples to equilibrate with water vapour. The stopcocks S_1 and S_2 were then closed to stop connection with water vapour and S_5 was opened. Heating under vacuum was again resumed and continued for 6 hours. These operations were repeated in cycle till the samples showed constancy in weight. Weighed capsules containing the flushed samples were then connected to the adsorption system and were allowed to equilibrate with the water vapour at a predetermined vapour pressure.

The adsorption/desorption experiments were carried

out at various vapour pressures of water developed by changing concentration of sulphuric acid in the receiver. In general equilibrium was established after 330 - 360 hours.

Results and Discussion

The helium, water and mercury displacement data are given in Table 2, which also indicates the total, micro and sub-micro pore volumes. The surface areas of the samples obtained by B.E.T. as well as from water vapour desorption isotherms have also been included in this table. The results show that all the samples have highly developed internal surface and that the surface area data obtained by the two methods are in general agreement.

Of all the samples studied, the imported one (No. 4, Table 1) shows maximum value for both surface area and pore volume. The corresponding values obtained with sample No. 3 are minimum. The difference between helium and water displacement values corresponds to the pore diameters in the range $5 - 10\text{\AA}$ i.e. in the sub-micro region. This value is maximum in case of sample No. 1 and minimum with No. 4. However, in case of the latter the difference between water and mercury displacement data is maximum.

Except for the iodine value of sample No. 3, the retention capacity of carbon with respect to methylene, iodine and hydrogen sulphide indicates that the samples prepared in this laboratory are better than the imported one. The most striking contrast is the poor hydrogen sulphide adsorption capacity of the sample No. 4. Comparing the data for sub-micro pore volume and adsorption capacity, it appears that hydrogen sulphide adsorption capacity of carbon is dependent on finer pores having diameters less than or equal to 10\AA . In other words, the sample having higher value of $D_{\text{H}_2\text{O}} - D_{\text{H}_2}$ will exhibit better adsorption capacity for low molecular diameter substances. But neither the surface area nor the total pore volume could on the basis of the experimental results predict

TABLE 2—SURFACE PROPERTIES OF ACTIVE CARBON SAMPLES

Sample	Sp. Surface by B.E.T. Method	Sp. Surface by Harvey's Method	He Displacement (D_{He}), cc/g.	H_2O Displacement ($D_{\text{H}_2\text{O}}$) cc/g.	Hg. Displacement (D_{H}) cc/g.	Pore volume, cc/g.
1.	716.8	756.77	0.392	0.525	1.426	1.034
2.	812.7	853.45	0.400	0.517	1.426	1.026
3.	752.5	765.05	0.396	0.505	1.433	1.037
4.	959.2	986.72	0.487	0.569	1.639	1.152

or explain, hydrogen sulphide, iodine and methylene blue adsorption characteristics of carbon.

All the adsorption isotherms (Figs. 2-4), except the one for the imported sample (Fig. 5) show similarity in pattern. It has been mentioned earlier that each of the samples studied took very long time to attain equilibrium. The fact that our experiments were conducted at pressure equal to the aqueous tension and not at atmospheric pressure may account for the delayed attainment of equilibrium. At pressure less than 1 atm., the mean free path of gas molecules is more than 10^{-3} cm. and this will cause diffusion restriction to call into play. Discussion on the rate of mass transfer through the pore of certain diameter at varying pressure of the system is beyond the scope of present discussion.

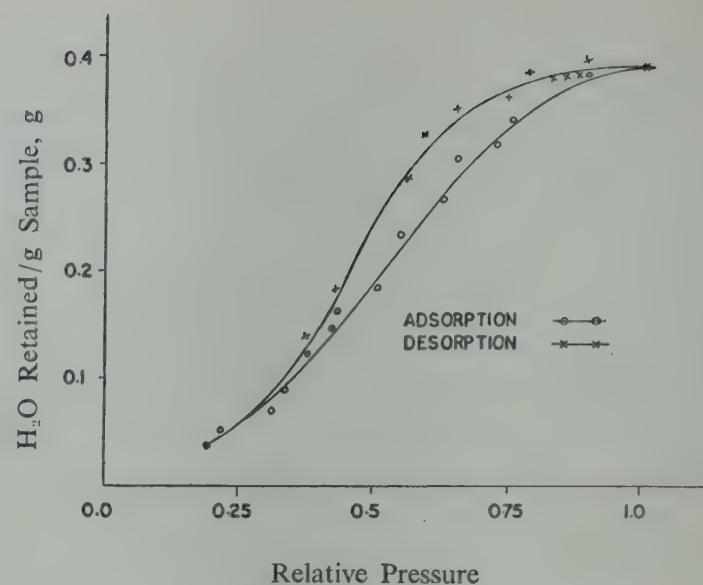


Fig. 4—Adsorption and Desorption Isotherms at 30°C (Sample 3)

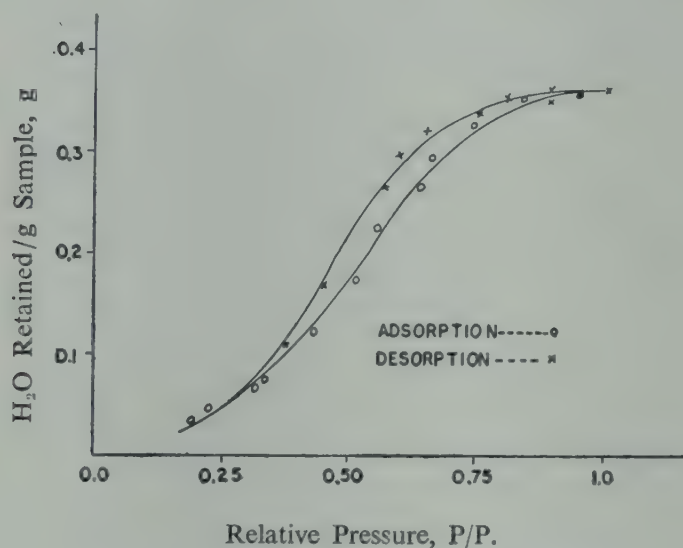


Fig. 2—Adsorption and Desorption Isotherms at 30°C (Sample 1)

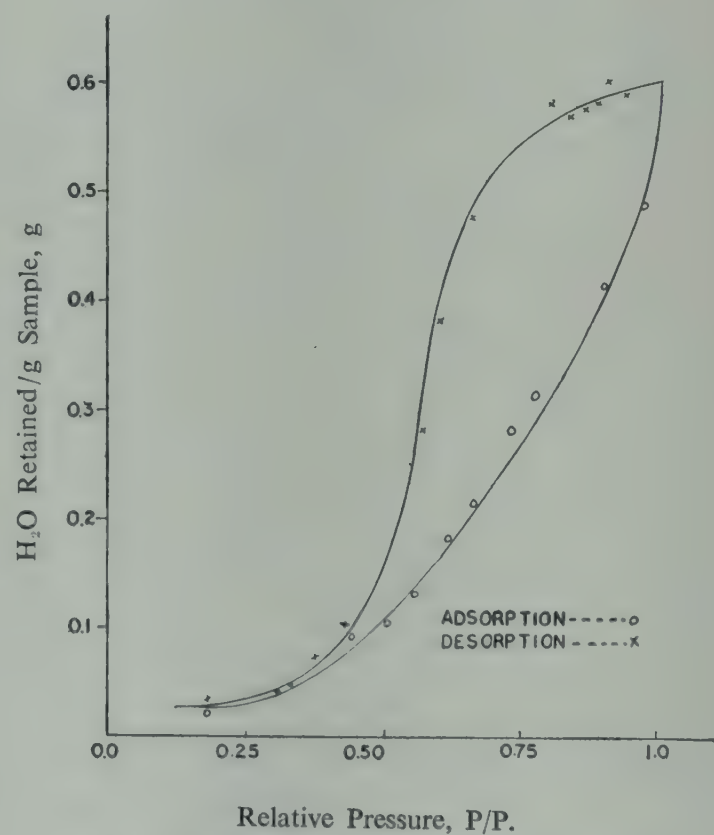


Fig. 5—Adsorption and Desorption Isotherms at 30°C (Sample 4)

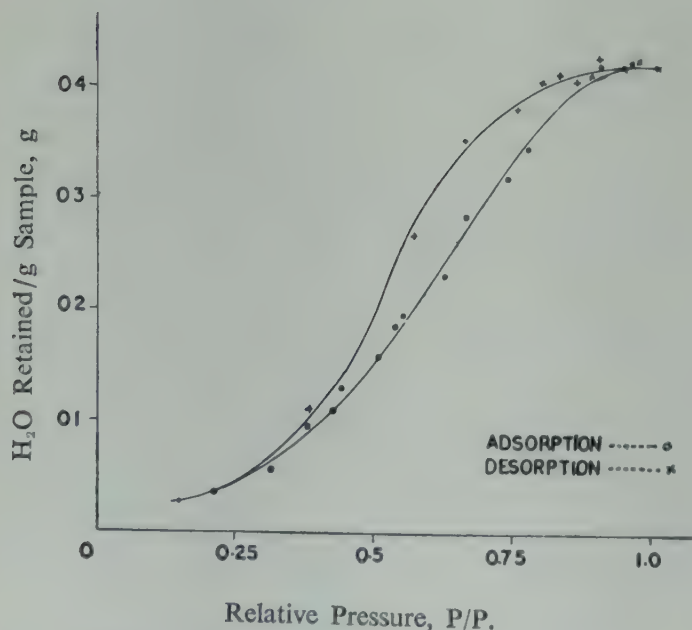


Fig. 3—Adsorption and Desorption Isotherms at 30°C (Sample 2)

From the desorption isotherm the surface area of the sample has been calculated according to Harvey³. Assuming complete wetting of the pore walls by the water vapour the contact angle was taken to be zero. Juhola and Wiig⁶, however, took the value of $\cos \theta$ less than 1 (equation 1). The value of θ varies with the degree of cleanliness and chemical nature of the surface, in a manner that there is complete wetting of the surface. Validity of this assumption is clear from the fact the surface area values calculated by this method

assuming the value of $\cos \theta$ and those obtained by applying B.E.T. equation are in close agreement.

Adsorption Isotherm: All the three samples prepared in this laboratory (samples 1, 2 and 3) show very close similarity in shape and form. In these cases the hysteresis loop starts in a narrow range of relative pressure between 0.20 and 0.25. But as a group these samples differ from the imported one in which case the loop starts at a lower relative pressure. In case of samples 1, 2 and 3, the adsorption and desorption rates are slow and gradual but for sample 4 the rate of adsorption is very fast at higher relative pressure. However, about the nature of hysteresis loops there is a general agreement, which suggests that the monolayer might not have been completed before the condensation started. Thus, all the curves satisfy the condition for calculation of surface area and pore size distribution.

From Table 2, it can be seen that the values of B.E.T. surface area are in close agreement with those calculated by Harvey's method. The surface area values were computed only up to a relative pressure where the two curves intercept. It has been found that if the pores beyond the lower limits of interception in the hysteresis loop are taken into consideration the values differ widely from the B.E.T. areas. This indirectly proves that the method is valid only when condensation occurs inside the pores.

It can be seen from the pore size distribution curves (Fig. 6) that there is a similarity in case of the samples prepared in this Division, and that all of them differ from the curve of the imported sample. The curve corresponding to sample 3, shows three peaks in-between $12.79\text{--}15\text{\AA}$, $15\text{\AA--}17.60\text{\AA}$ and $17.6\text{--}21\text{\AA}$. The peak in the low pore region between $12.79\text{--}15\text{\AA}$ appears to be very significant. In case of other two prepared samples, the maximum distribution is in the region of 12.76 to 29\AA . The peak of the imported samples is shifted to the higher pore region and maximum number of pores appears to be in the region 18.00 to 31.64\AA .

The size distribution curves obtained with samples 1, 2 and 3 throw some light on the effect of activating agent and temperature on the porosity of carbon. Increase of zinc chloride concentration causes improvement in M.B. adsorption capacity, but its adsorption capacities for iodine and hydrogen sulphide gets deteriorated presumably due to widening of fine pores having diameter in the region lower than those covered by the distribution curve. That a fraction of the sub-micro pores are enlarged is clear from the change in the values of $(D_{H_2O}-D_{He})$. The combined effect of increase the concentration of activating agent and tem-

perature causes appearance of more pores in the region corresponding to the peaks shown in the curve of sample 3. From the difference in the $(D_{H_2O}-D_{He})$ values of the samples 2 and 3, it is clear that the appearance of these pores cause further decrease of submicro pore aggregate. Incidentally the region in which new pores appear are not appropriate for either hydrogen sulphide or iodine adsorption. The net effect is that adsorption capacity for both of these gets deteriorated and the MB adsorption property is improved.

It is understood that adsorption capacity of carbon for a particular substance in general is a function of the distribution of pores. Evaluation of pore size distribution is, therefore, considered as a valuable method for selection of a carbon for specific adsorption capacities. The distribution curve (Fig. 6), however, does not include any pore below 12.79\AA . As a matter of fact, for the correction factors stated before it is not possible to determine the diameter of pores in the submicro region by water vapour adsorption/desorption methods. Further, if pores having diameter

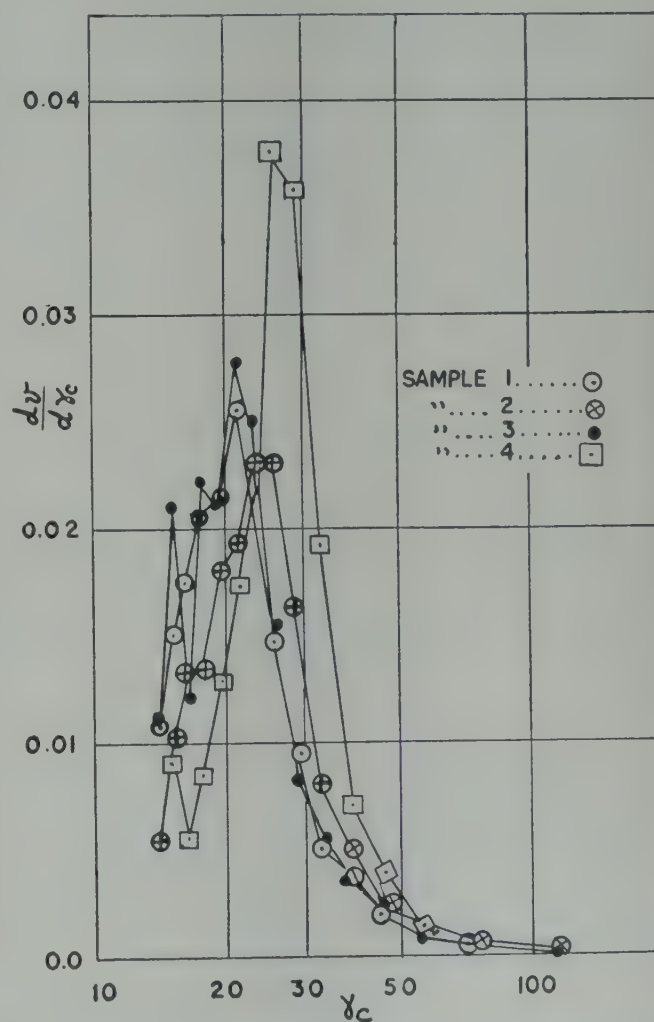


Fig. 6—Pore size distribution in three samples of active carbon prepared from lignite and $ZnCl_2$ and one commercial carbon.

(γ_c denotes pore radius in \AA)

less than the lower limits shown in the distribution curves are taken into account, the surface area values calculated differ widely from those obtained by B.E.T. method. Thus any attempt to extrapolate the curves beyond the lower limits of pore diameters indicated may lead to erroneous results. The value of diameter of the smallest size pores obtainable by this method is many times greater than the diameter of any of the molecules studied for adsorption. Obviously pores in this region of diameter are incapable of precisely defining the specificity of the carbon samples studied.

The difference between water and helium displacement values (Table 2) corresponds to the total volume of pores having diameter between 5 and 10Å. The results presented in this table, however, indicate that there is some relationship between ($D_{H_2O}-D_{He}$) values and hydrogen sulphide adsorption. The maximum pore volume in this region is associated with maximum hydrogen sulphide adsorption and the lowest value accounts for the minimum.

Summary: It appears that the pore size distribution curves obtainable from water vapour adsorption/desorption method, though to some extent that can explain the specificity for adsorption of methylene blue, cannot be utilized in selecting a carbon suitable for iodine and hydrogen sulphide adsorption. The measurement

of surface area and total pore volume also does not throw any light on specificity of carbon with respect to adsorption of M.B., iodine and hydrogen sulphide.

One of the most valuable tools to ascertain suitability of carbon for adsorption of hydrogen sulphide appears to be the measurement of pore volume in the region 5 to 10Å by helium and water displacement methods. This investigation also indicates that increase in zinc chloride concentration beyond 100 per cent enlarges the fine pores making the active carbon less suitable for hydrogen sulphide as well as iodine adsorption. Increase in activation temperature beyond 800°C has also a deteriorating effect on hydrogen sulphide and iodine capacity of active carbon prepared from lignite and zinc chloride.

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Efficiency of Various Forms of Phosphate in Crop Plant Nutrition

Part III: Response of Potato in Field Trials

By

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Field trials at Sindri have shown that citrate-soluble phosphates, viz. calcined phosphate and multiphosphate (18 per cent water-soluble P_2O_5), are by no means inferior to a completely water-soluble phosphate, viz. superphosphate, even in case of potato. Citrate-soluble phosphates might have considerable fertilizer value in short duration crops also.

Thorne et al⁶ noted from a number of field trials that for all crops and fertilizers there was no definite relationship between the water solubility of phosphate in fertilizers and the relative increase in crop yields. Rogers² found that nitrophosphate with 40 per cent water-soluble P_2O_5 can favourably compare with concentrated superphosphate. Russell³ observed that dicalcium phosphate was sufficiently soluble to maintain an adequate supply of $H_2PO_4^-$ ions and more so in acidic soils. Barbier⁴ noted that as 1-2 mg. of phosphate P_2O_5 /l. was all that was necessary for optimum uptake by the plants and the solubility of dicalcium phosphate being 20-100 mg./l. it was as good as superphosphate for all practical purposes. In Ceylon⁵ no appreciable difference in response to different forms of phosphates was noted. Trials at Pattambi⁶ proved that dicalcium phosphate when broadcast to paddy at 80 lbs. P_2O_5 /ac. was better than superphosphate at the same level*.

At C.R.R.I.**, Cuttack⁷ and in most model agonomic experiments⁸, water-insoluble forms of phos-

phorus were as good as water-soluble forms. Using tracer technique, Dutta⁹ noted that phosphate uptake was more from the citrate-soluble dicalcium phosphate than from any other soluble phosphate in calcareous soils. Experiments at Fertilizer Trials Station, Sindri¹⁰ on clayey soil (pH 8.4) have shown that at higher level of application, efficiency of water-soluble phosphates is at par with that of water-insoluble phosphates.

Potato, a major vegetable in our diet, produces more food per unit area than any other vegetable crop and consumes a high amount of phosphatics, while adequate availability of the phosphatics in water soluble forms in this country remains a problem. Therefore, the object of the present study was to find out whether other varieties of phosphates could make a headway to solve this problem.

Experimental

The trial site selected was in one of the homogeneous plots of the Fertilizer Trial Station, of this Division at Sindri (Table 1). It was uniform from all points of view. Care was taken to maintain as far as possible uniformity in selecting seeds, planting, fertilizer application, etc.

The land was opened after monsoon at optimum moisture condition to ensure a good tilth. A tractor-drawn disc plough was used for the purpose. Ploughing

*The author (S.P.D.) had discussions with Dr. G. L. Turman of the Tennessee Valley Authority, USA, on the crop response of water and citrate-soluble, finely divided phosphates when these are mixed thoroughly with the soil. Dr. Turman had observed that the responses of the two forms of phosphate tend to be similar and in the case of the latter the degree-response increases with increases in surface area of the particles.

**Central Rice Research Institute.

TABLE 1—ANALYSIS OF SOIL SAMPLES
(On Oven-Dry Basis)

A. Mechanical Analysis, %			
Clay	..	28.21	
Silt	..	20.97	
Sand	..	44.82	
B. Chemical Analysis			
Organic Carbon, %	..	1.19	
Total Nitrogen %	..	0.161	
Total P ₂ O ₅ %	..	0.178	
Total K ₂ O %	..	0.912	
PH	..	8.1	

was completed on the same day keeping the head-land always outside the experimental area. After a week the land was brought to a fine tilth by ploughing and harrowing uniformly without any break. The final lay-out of the experiment was then completed. The experiment was fitted in a randomized block design with two replications. Gross plot size was 25' × 6' and spacing between rows and hills was 1½' and 9" respectively. The variety of potato used was Royal Kidney. The tubers were cut so that the average size of the cut seed pieces were 1 to 1.5 oz. The freshly cut tubers were soaked in Agallol for one minute and planted in trenches. In each plot the number of rows and hills was constant. Planting was completed in one day i.e. on 3rd December, 1964. The tubers were then covered with fine loose soil making small ridges for each row.

All the fertilizers were properly sampled and analysed¹¹ for their nutrient contents. The calculated quantities of all the fertilizers were applied as basal in trenches and mixed thoroughly in the soil before planting the seeds (Table 2).

0.03 per cent solution of Folidol E-605 was sprayed once on 21.1.65 as a preventive measure against insect and pests. Fungal attacks were prevented completely by spraying phytolan on 19.1.65 and 28.1.65. Finally the crop was harvested on 23.3.65 leaving the discards, and the yield data was recorded from the net plot size of 23.5' × 3'.

The methods followed for chemical analysis of the potato tubers were the same as those followed earlier¹⁰.

Results and Discussion

Growth habits of the potato plants indicated that at all the three levels there was very little difference amongst the different phosphatic sources. Irrespective of them the plants in the third level treatments were

TABLE 2—FERTILIZER CALCULATIONS

Sl. No.	Fertilizers	P ₂ O ₅ , lbs/acre	Amount of Fertilizer, g./plot
1.	C ₁	50	269
2.	C ₂	100	539
3.	C ₃	200	1078
4.	M ₁	50	198
5.	M ₂	100	396
6.	M ₃	200	792
7.	F ₁	50	354
8.	F ₂	100	709
9.	F ₃	200	1418
10.	S ₁	50	434
11.	S ₂	100	868
12.	S ₃	200	1735
13.	Control	0	0

C₁ - C₃ multiphosphate; M₁ - M₃ calcined phosphate; F₁ - F₃ fused phosphate; S₁ - S₃ superphosphate. 50 lbs/ acre = 269g./ plot

TABLE 3—YIELD OF POTATO TUBERS, KG./PLOT
(Each figure represents an average two replicates.)

Treatment	Average yield, kg.
Control	0.65
M ₁	1.20
M ₂	1.85
M ₃	2.05
F ₁	0.70
F ₂	1.00
F ₃	1.45
C ₁	1.85
C ₂	2.30
C ₃	2.45
S ₁	2.00
S ₂	2.25
S ₃	2.35
'F' value for the Treatments	4.40**
C.D. at the 5% Level	0.926

most vigorous in respect of vegetative growth followed by the second and the first level-treatments.

Yield of Potato Tubers: Multiphosphate produced in general higher tuber yields followed closely by superphosphate, calcined phosphate and fused phosphate (Fig. 1). At the 5 per cent level of significance, there was no difference in yields from the superphosphate, multiphosphate and calcined phosphate treated plants at all the three levels. Fused phosphate produced signi-

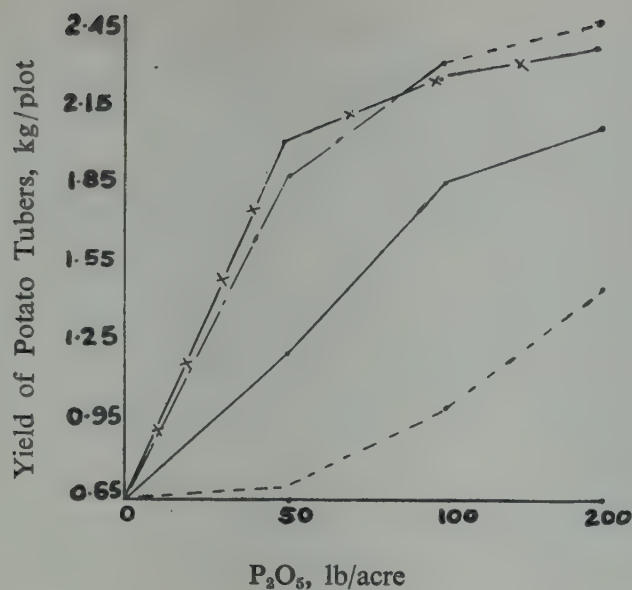
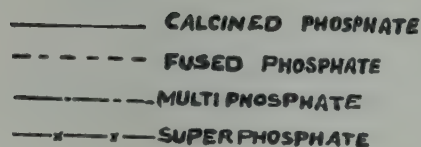


Fig. 1



ficantly lower yields at all the three levels probably due to its higher fluorine content.

Percentage of N,P and K in Potato Tubers (Table 4): As it is quite apparent from Figs. 2 to 4, there was an increase in the percentage of nitrogen and P_2O_5 in the tubers due to the increased rates of phosphorus applications. The reverse trend was noted in the case of potassium probably due to a limited availability of the nutrient in the soil. The trend of nitrogen percentage in the potato tubers at the 3rd level of treatments was $M_3 > F_3 > C_3 > S_3$. At the 2nd level it was $C_2 > M_2 > F_2 > S_2$ and at the first level $F_1 >$

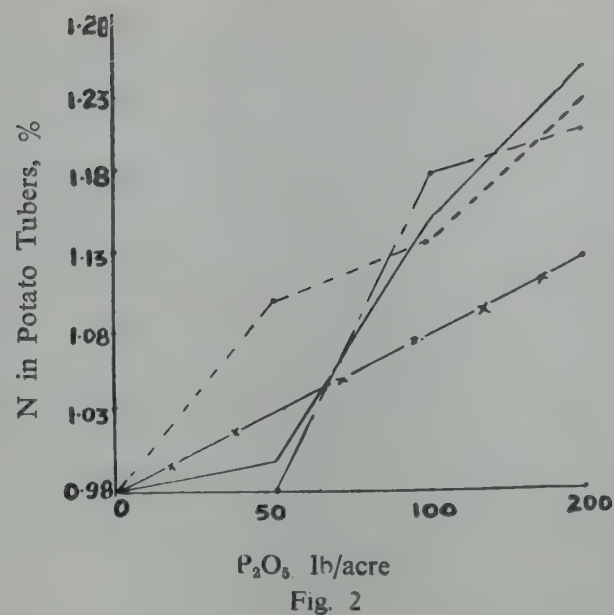


Fig. 2

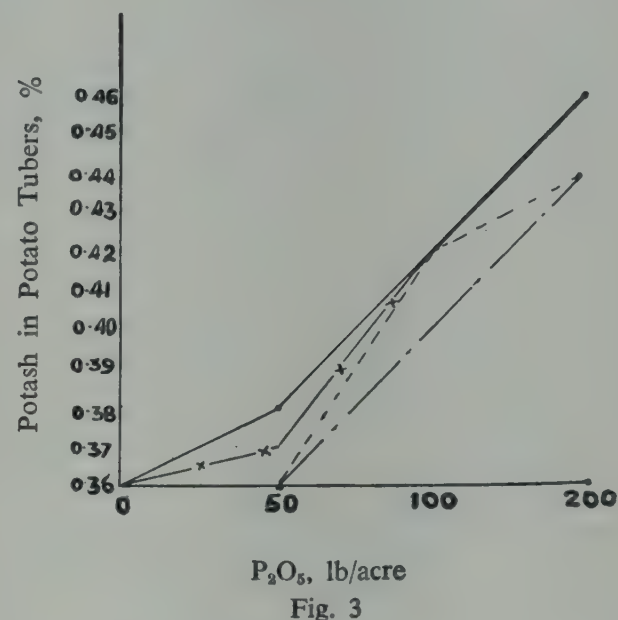


Fig. 3

TABLE 4—UPTAKE OF N, P_2O_5 & K_2O BY POTATO TUBERS, %

Treatment	N	P_2O_5	K_2O
Control	0.98	0.36	2.24
M_1	1.00	0.38	2.03
M_2	1.15	0.42	1.82
M_3	1.25	0.46	1.78
F_1	1.10	0.36	2.13
F_2	1.14	0.42	2.03
F_3	1.23	0.44	1.96
C_1	0.98	0.36	2.03
C_2	1.18	0.40	1.96
C_3	1.21	0.44	1.82
S_1	1.03	0.37	2.03
S_2	1.08	0.42	1.90
S_3	1.13	0.46	1.84

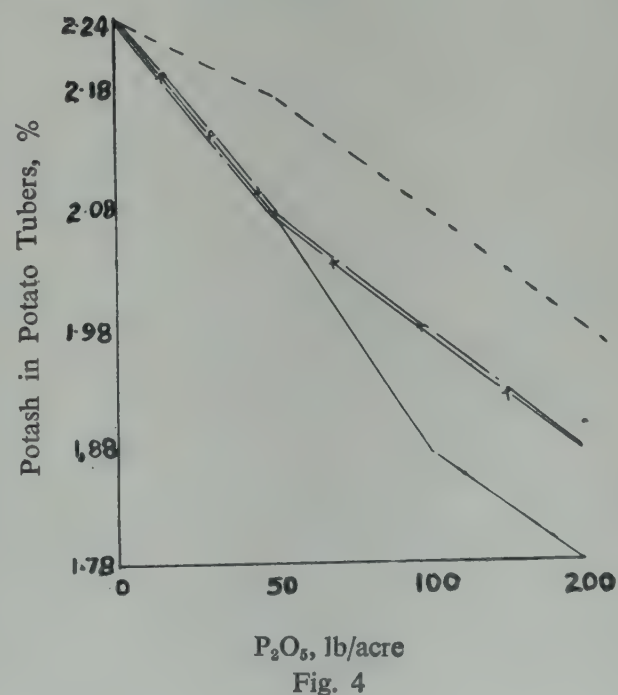


Fig. 4

$S_1 > M_1 > C_1$. Control plants had the lowest percentage of nitrogen in the tubers. There was a little difference in the percentage of P_2O_5 in the potato tubers due to the different fertilizer treatments. Control plants had the lowest values in this respect. A similar trend was noticed in the case of K_2O in the tubers; in this case control plants had the highest content of K_2O in their tubers.

It is quite apparent from these findings that except in the case of fused phosphate which contains about 1.8 per cent fluorine there is very little difference between the citrate and water-soluble varieties of phosphates in enhancing growth and yield of potato tubers.

Acknowledgements

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Studies on the Relative Efficiencies of Nitrophosphate and other Nitrogenous and Phosphatic Fertilizer Combinations

I: Response of *Aman* Paddy in Field Trials

By

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In field trials with *Aman* Paddy grown under puddled conditions, it was observed that nitrophosphate (nitrogen 12.9 and total P_2O_5 12.9 per cent) was by no means inferior to equivalent applications of nitrogen and P_2O_5 as ammonium sulphate \rightarrow superphosphate or ammonium nitrate-superphosphate or ammonium phosphate sulphate.

Tanaka¹ et al found that nitrate and ammonium nitrogen were equally good for rice at a moderate level of application (20 ppm) but the former, at higher level (100 ppm) was definitely superior. Mukherjee² and Ghose³ et al expressed similar views under W. Bengal conditions. Dastur⁴ and Pirzada et al⁵ observed

that a mixture of ammonium and nitrate nitrogen was superior, while Wyche⁶ obtained similar yields from either forms used individually. In case of top dressing, Mitra and Gupta⁷ found that ammonium sulphate, niciphos II and ammonium nitrate were equally effective. Navalkar⁸ concluded from his findings

that a mixture of ammonium sulphate and ammonium nitrate was superior to ammonium sulphate when applied alone. Experiments at I.A.R.I.⁹ indicated ammonium sulphate, ammonium sulphate-nitrate and ammonium chloride to be at par in increasing the yield of paddy.

Experiments at Mangalore and Pattambi¹⁰, Burdwan¹¹, Petru¹²⁻¹³, (Madras). Hirigur (Mysore)¹⁴⁻¹⁶, Khudwani¹⁷ (Punjab) and Shalimar¹⁸ (Punjab) indicated identical performance of ammonium sulphate and Chilean nitrate on paddy. At Badhan¹⁹ ammonium nitrate was superior to ammonium sulphate while both were at par at Pusa²⁰. Panse and Khanna²¹ concluded from more than 7,600 experiments that, for rice plants, urea, ammonium sulphate nitrate and calcium ammonium nitrate were about equally good and superior to ammonium sulphate.

Substantial evidences are available indicating that sparingly water solubility of phosphates in most cases does not, in any way, impair the availability of phosphorus to rice plants. Experiments carried out at C.R.R.I. Cuttack³ and in Model Agronomic Experiments²² showed that sparingly water insoluble forms of phosphorus were as good as water soluble forms. Experiments conducted at this Division's Fertilizer Trial Station at Sindri²³ on clayey soil (pH 8.4) showed that in the case of paddy, sparingly soluble phosphates are equally efficient as the water-soluble phosphates in encouraging growth and yield.

The present investigation was undertaken to evaluate the relative merits of various combinations of ammonium nitrogen, nitrate nitrogen citrate-soluble P_2O_5 and water-soluble P_2O_5 in encouraging growth and development of wet land paddy.

Experimental

The experimental site in the Fertilizer Trial Station was carefully selected avoiding drains or ditches and big trees by the side of the plot. The plot was fairly uniform in respect of fertility, slope (Table 1), drainage and various other physical and chemical conditions.

First ploughing of the experimental area was done in June 1964 without any break with a disc plough, the headland being always kept outside the experimental area. The ploughed area was left as such until it was finely puddled and laddered uniformly on 2nd August, 1964. Considering all the agroclimatic conditions of the locality and varietal characters of different varieties of paddy, *Patnai-23* variety of *Aman* paddy was chosen as the test crop. Japanese method³ was followed in seed selection, seed bed preparation and

TABLE 1—ANALYSIS OF SOIL SAMPLES
(On Oven-Dry Basis)

A. Mechanical Analysis		
Clay	..	27.95
Silt	..	21.22
Sand	..	45.95
B. Chemical Analysis		
Organic Carbon, %	..	1.211
Total Nitrogen %	..	0.154
Total P_2O_5 %	..	0.185
Total K_2O %	..	0.941
pH	..	8.40
Base-Exchange Capacity meq./100 gm. Soil	..	24.151
Exchangeable Bases, meq./100 gm. Soil		
(a) Exchangeable K^+	..	0.361
(b) -do- Na^+	..	1.176

sowing of seeds except that the seed beds received no manures and fertilizers.

Micro plot technique as developed in Rothamsted²⁴ was followed, the effective plot area being 1/946.9th of an acre. The final layout of the plot was completed after the final land preparation, each plot being well separated by 'ails' and drains. Randomised block design was used for this experiment. There were all provisions for irrigating the plots individually thus restricting the movement of the nutrients from one plot to the other.

All fertilizers were sampled, and analysed for their nutrient content before application. Calculated quantities of the fertilizers were weighed (Table 2) and spread uniformly over the randomly allocated plots and mixed thoroughly with the soil immediately before transplanting, avoiding human error as far as practicable. Plot size of the treatments was 25' × 4', spacing between rows and hills being 12 and 8 inches respectively. Special coir strings marked at definite intervals were used for transplanting at fixed spacings. Five weeks old seedlings were uprooted with sufficient care and transplanted on the same date i.e. on 5.8.64, three seedlings being put per hill.

A steady level of water (approx. 4") was maintained in all the plots. Two weeding operations were done and a 0.03 per cent solution of Folidol E-605 was sprayed two times as a preventive measure against pest attacks.

Regular growth measurements in terms of rate of increase in height, number of tillers, length of panicles, etc. were made. For determining the nutrient contents of fertilizers, plants and soils, the previous

TABLE 2—APPLICATION OF FERTILIZERS IN THE SOIL

Sl. No.	Abbreviations	Name of Fertilizers	Lbs of P ₂ O ₅ /acre	Lbs of N/acre	g. of N & P Fert./Plot	g. of N Fert./Plot
1.	N—1	Nitrophosphate	50	50	397.33	—
2.	N—2	Nitrophosphate	100	100	794.66	—
3.	APS—1	Ammonium phosphate sulphate	50	50	84.30 Am. phos	204.00 Am. Sulph.
4.	APS—2	Ammonium phosphate sulphate	100	100	168.60 „	408.00 „
5.	SPAS—1	Superphosphate and ammonium sulphate	50	50	289.17 Superphos.	253.90 „
6.	SPAS—2	Superphosphate and ammonium sulphate	100	100	578.34 „	507.80 „
7.	SPAN—1	Superphosphate and ammonium nitrate	50	50	289.17 „	148.71 Am. Nitrate
8.	SPAN—2	Superphosphate and ammonium nitrate	100	100	578.34 „	297.42 „
9.	SP—1	Superphosphate	50	0	289.17 „	—
10.	SP—2	Superphosphate	100	0	578.34 „	—
11.	AS—1	Ammonium sulphate	0	50	—	253.90 Am. Sulph.
12.	AS—2	Ammonium sulphate	0	100	—	507.80 „
13.	Cont.	Control	0	0	—	—

methods²⁵ were followed. The crop was harvested on 19.12.64 and random samples of plants were taken for different agronomical studies.

Results and Discussion

Effect of Fertilizer on Growth and Development of Aman Paddy Plants: It is quite clear from Figs. 1 & 2 that both at 50 and 100 lbs. levels there was very little difference in heights within nitrophosphate, superphosphate-ammonium nitrate, superphosphate-ammonium sulphate and ammonium phosphate sulphate treated plants. Although both ammonium sulphate and superphosphate treated plants were inferior to the other treatments, ammonium sulphate treated plants, probably because of the effect of nitrogen on vegetative growth, were taller than superphosphate treated plants. Control plants were the dwarfest. Figs. 2 to 8 indicate quite clearly that during the entire growth period plants receiving 100 lbs. levels of nutrients were taller than those receiving 50 lbs. levels. Control plants were inferior in all respects. The number of tillers produced by the different fertilizer treated plants followed the same trend, observed in the case of heights. Almost similar numbers of tillers (Figs 9 & 10) were produced by the nitrophosphate, ammonium phosphate sulphate, superphosphate-ammonium nitrate and ammonium sulphate-superphosphate treated plants at both 50 and 100 lbs. levels. The superphosphate and ammonium sulphate treated plants were distinctly inferior in this respect. Control plants produced the minimum number of tillers.

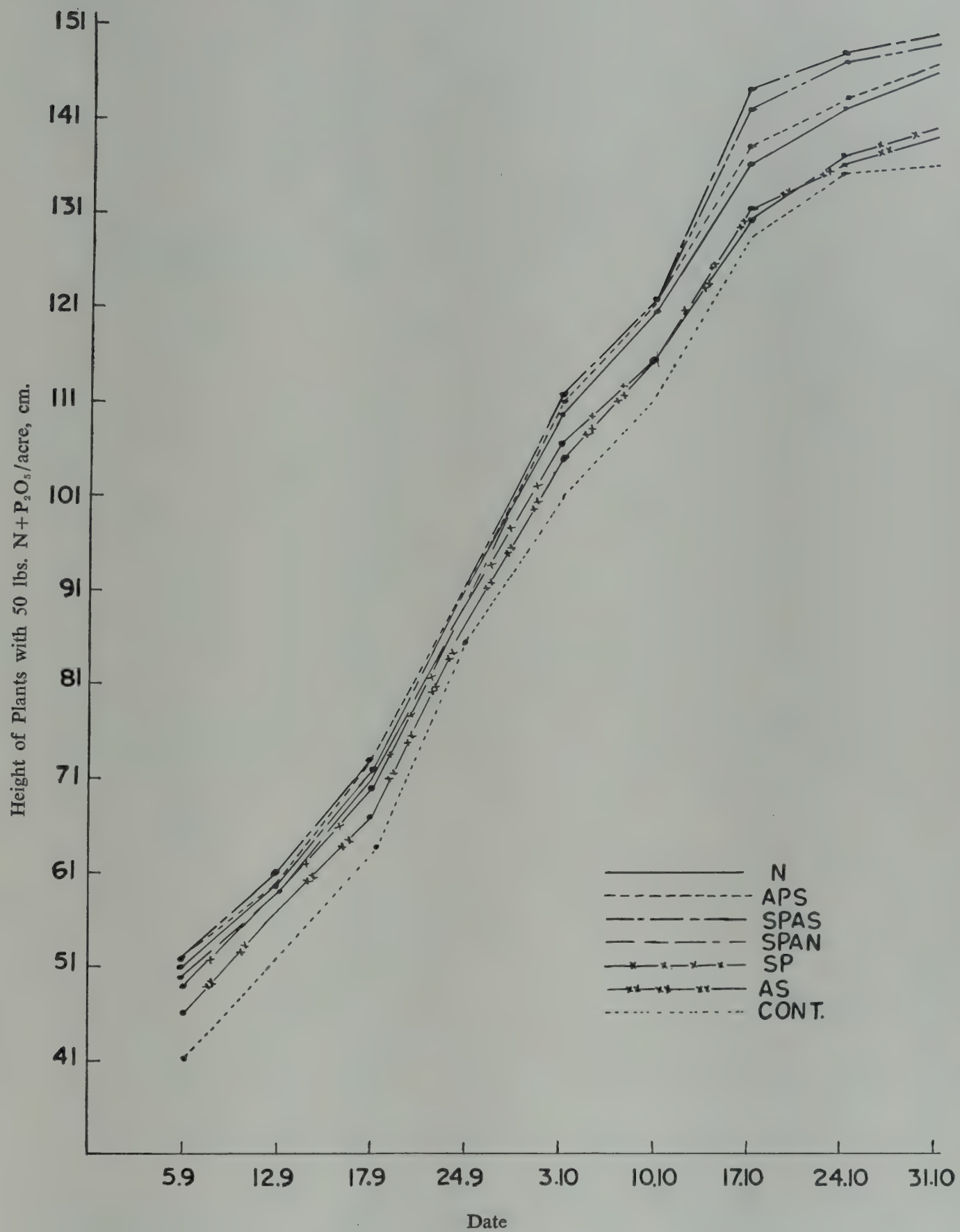
In all the fertilizer treatments (Figs 11 and 12), 100 lbs.

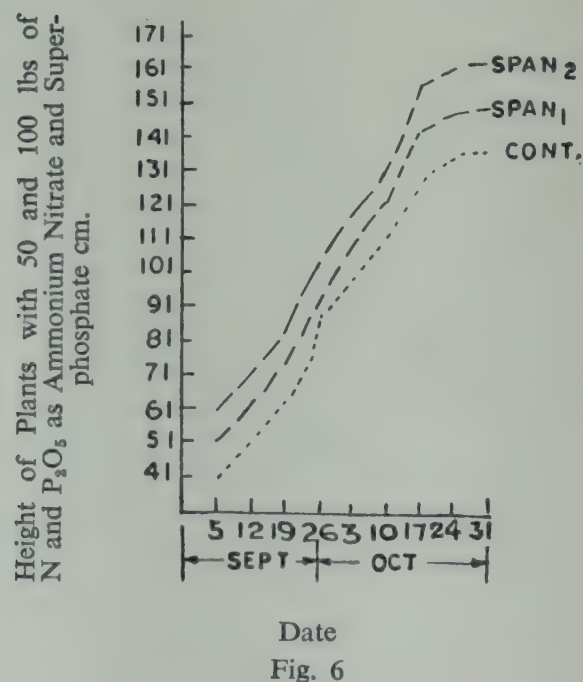
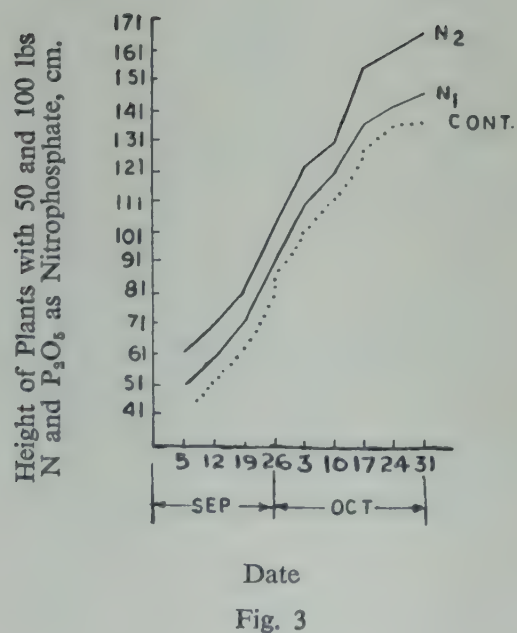
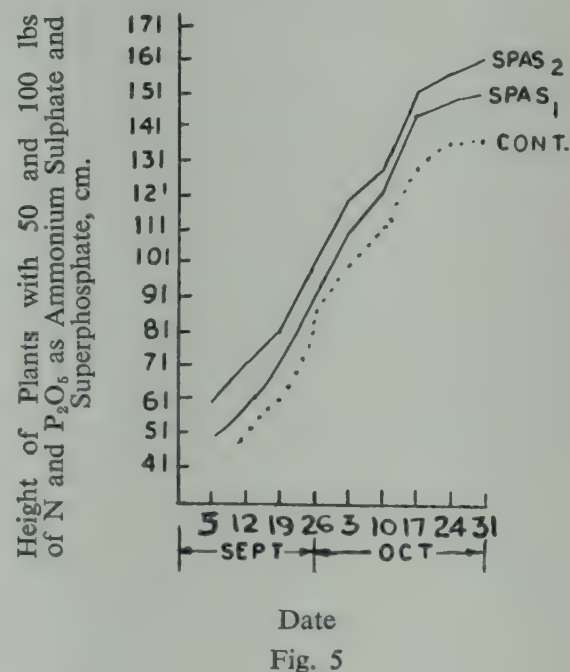
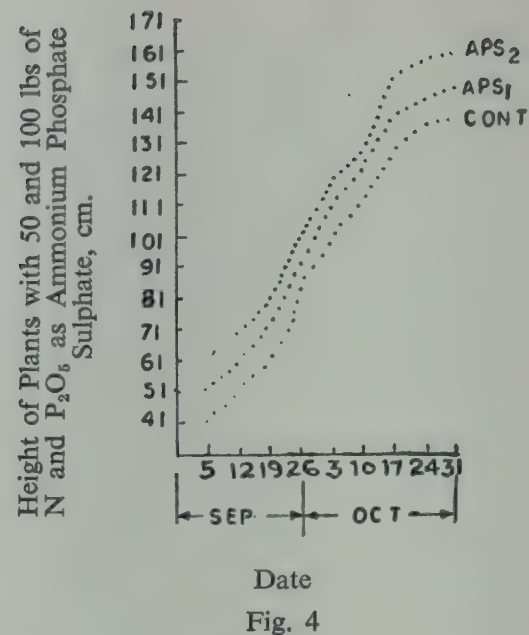
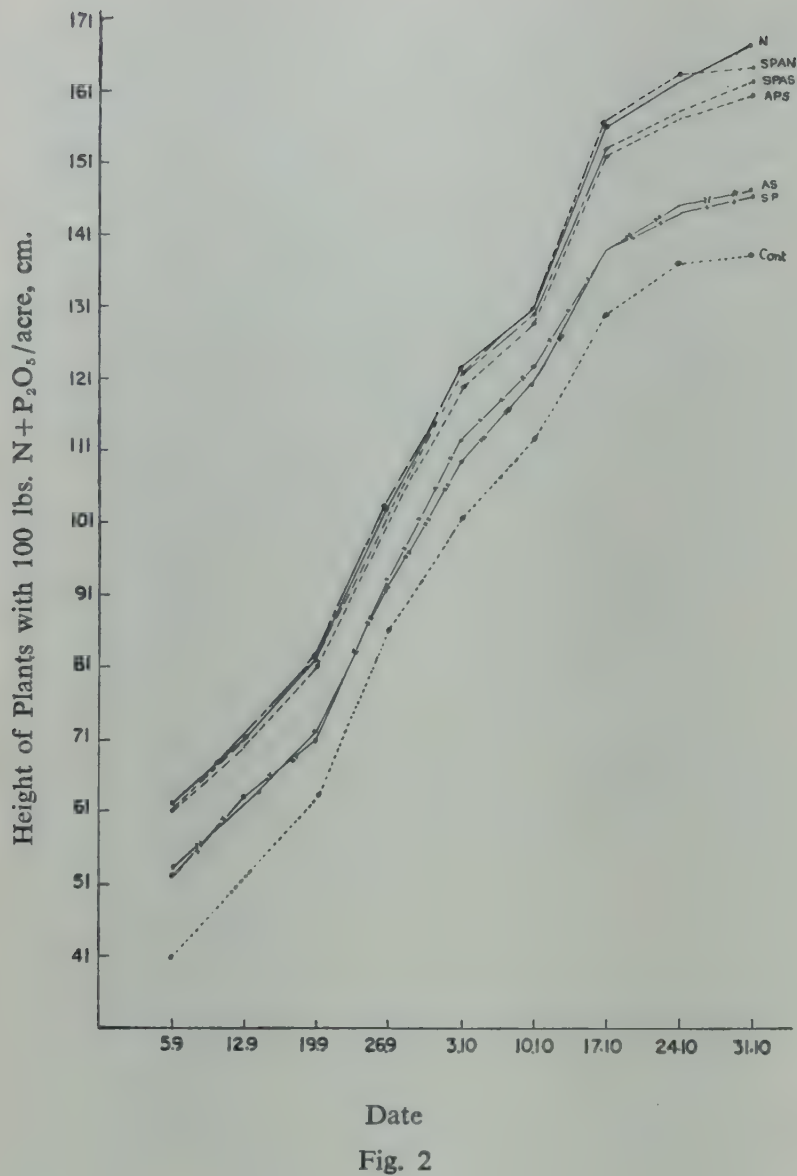
treated plants had significantly more number of tillers than the 50 lbs. treated ones. Control plants were the lowest in this respect.

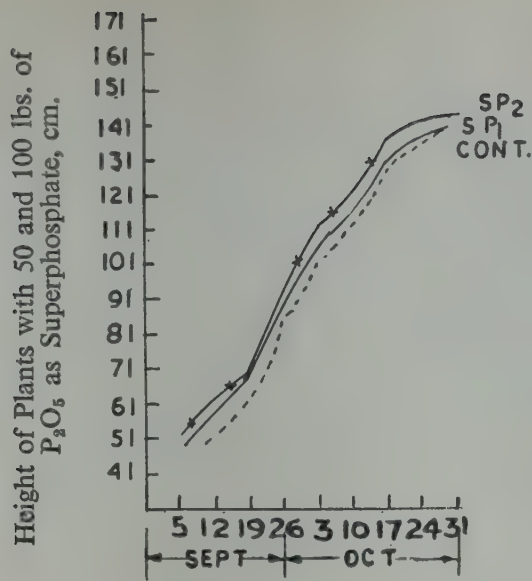
Yield of Rice Straw and Grains (Table 3, Fig. 17): At the 5 per cent level of significance, there was no significant difference within nitrophosphate, superphosphate-ammonium sulphate, ammonium phosphate sulphate and superphosphate-ammonium nitrate treatments at both 50 lbs. and 100 lbs. levels. Ammonium sulphate treatment produced slightly higher yields over super-

TABLE 3—YIELD OF RICE STRAW AND GRAINS, KG/PLOT
(Each figure represents an average of two replicates.)

Treatments	Yield of Straw	Yield of Grains
N ₁	7.52	2.90
N ₂	8.45	3.12
APS ₁	7.77	2.77
APS ₂	8.12	2.97
SPAS ₁	7.80	2.85
SPAS ₂	8.37	3.07
SPAN ₁	7.62	2.77
SPAN ₂	8.25	3.07
SP ₁	6.05	2.47
SP ₂	6.27	2.62
AS ₁	7.12	2.50
AS ₂	7.62	2.65
Control	4.77	2.27
'F' Value for the Treatments	107.53***	43.71***
C.D. at 5% Level	0.326	0.113

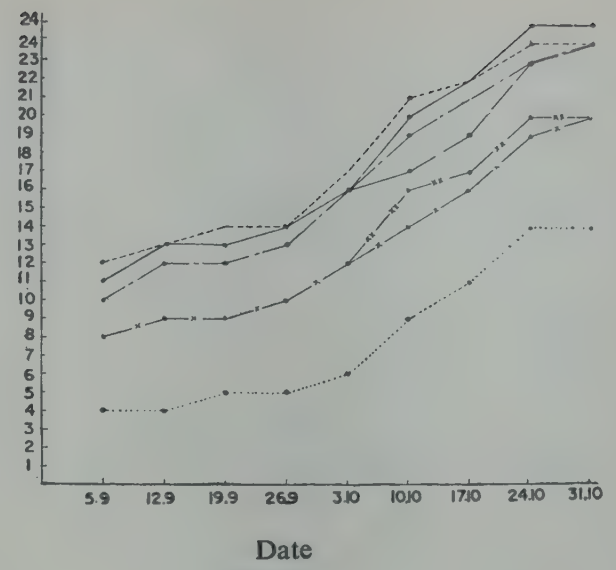




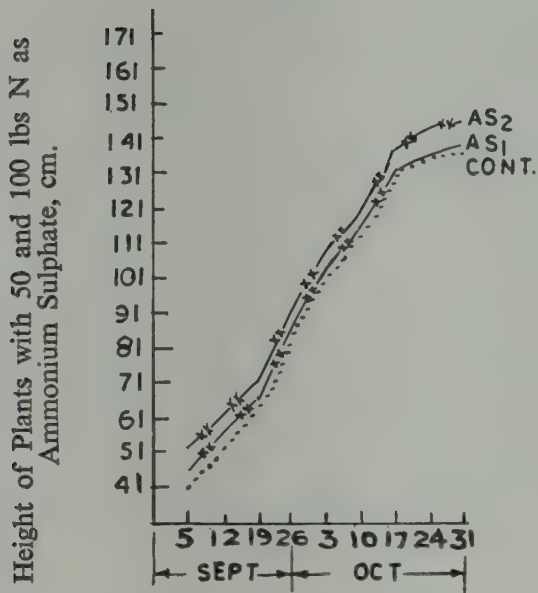


Date
Fig. 7

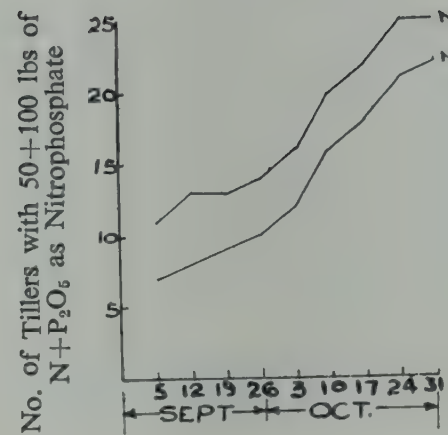
No. of Tillers with 100 lbs of N + P_2O_5 /acre



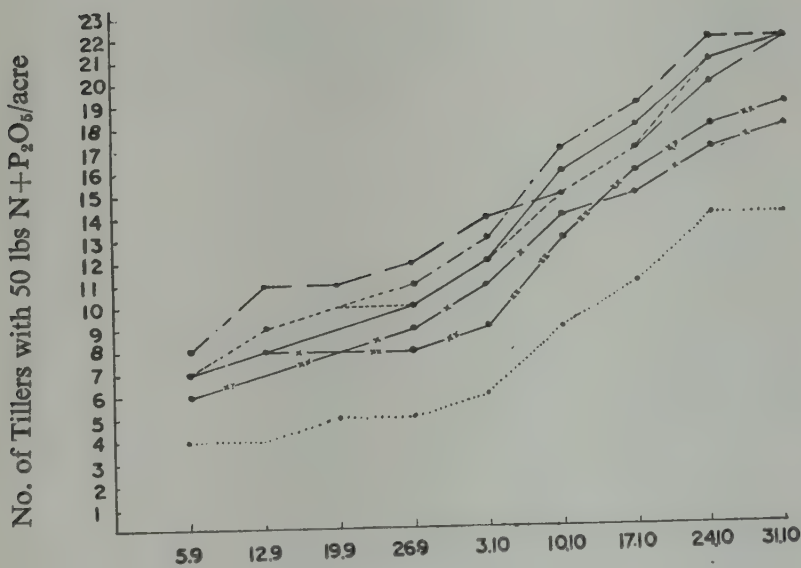
Date
Fig. 10



Date
Fig. 8

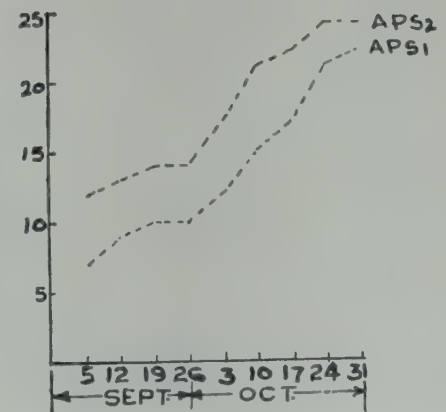


Date
Fig. 11



Date
Fig. 9

No. of Tillers with 50+100 lbs of $N+P_2O_5$ as Ammonium Phosphate Sulphate



Date
Fig. 12

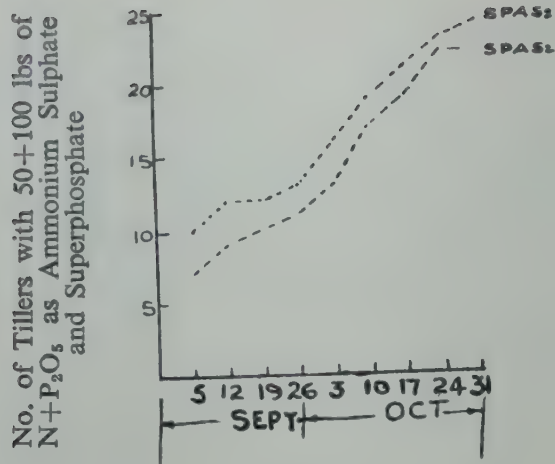


Fig. 13

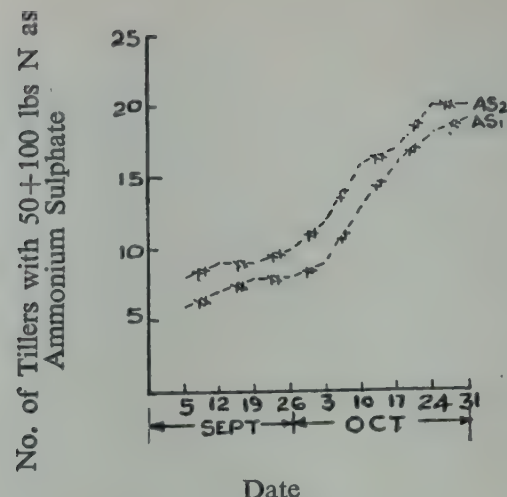


Fig. 16

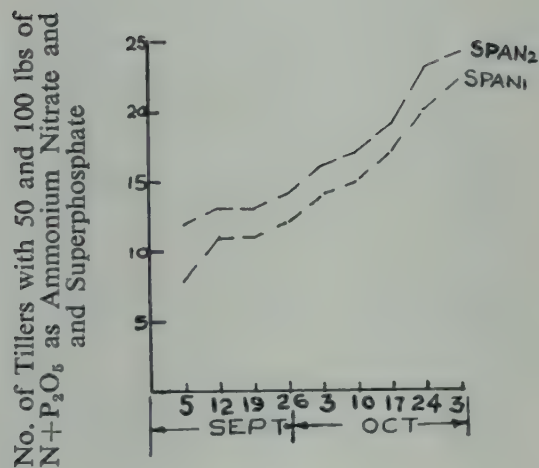


Fig. 14

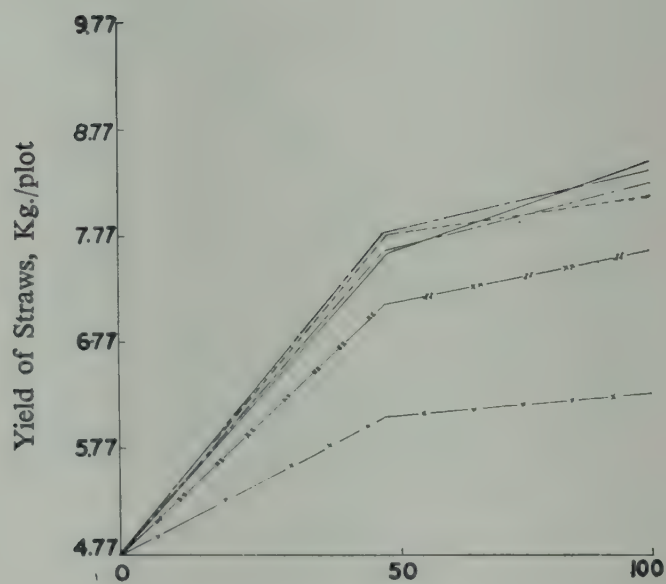


Fig. 17

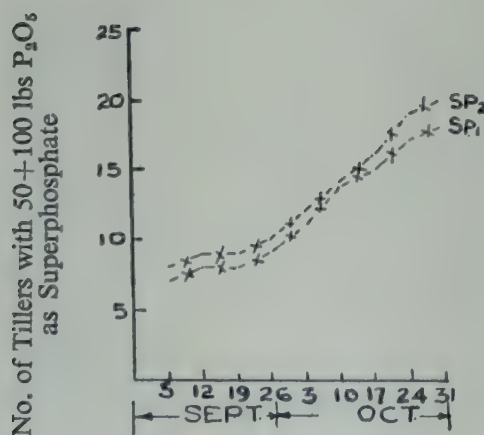


Fig. 15

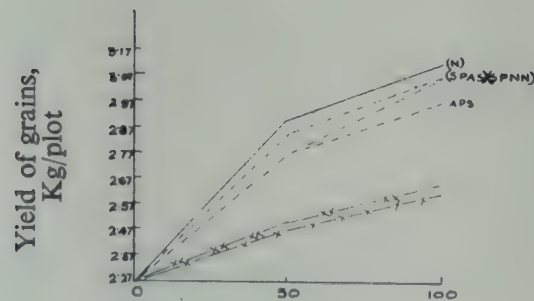


Fig. 18

phosphate-treated plants at both the levels. Control plants produced the lowest yields.

In the case of rice grains also (Table 3, Fig. 18) almost the same trend in yield was noticed. Ammonium phosphate sulphate treated plants produced slightly lower yields than the nitrophosphate, superphosphate-ammonium sulphate and superphosphate ammonium nitrate treated ones. Although superphosphate and ammonium sulphate treated plants produced lower yields than all other treatments there was no difference in yield between these two treatments at both the levels. Control plants produced the lowest grain yields.

Uptake of Nitrogen by the Rice Plants: (Table 4, Fig. 19) Total uptake volumes of nitrogen demonstrated quite clearly that at the 5 per cent level of significance there was no difference in uptake from nitrophosphate, ammonium phosphate sulphate, superphosphate-ammonium sulphate and superphosphate-ammonium nitrate treatments at both the levels. Ammonium sulphate treated plants although inferior to all the other treatments took up significantly more nitrogen than the superphosphate-treated plants. Control plants took up the least amounts of nitrogen.

Uptake of Phosphate by the Rice Plants (Table 5, Fig. 20): As in the case of uptake of nitrogen there was no significant difference at the 5 per cent levels in the uptake of phosphorus from nitrophosphate, ammonium phosphate sulphate, superphosphate-ammonium sulphate and superphosphate-ammonium nitrate treat-

TABLE 5—UPTAKE OF PHOSPHATE (P_2O_5) BY RICE PLANTS G./PLOT

(Each figure represents an average of two replicates.)

Treatments	Rice Straw	Rice Grains	Straw + Grains
N ₁	18.86	11.60	30.46
N ₂	22.01	14.06	36.07
APS ₁	18.66	11.10	29.76
APS ₂	21.93	13.02	34.95
SPAS ₁	18.72	11.72	30.44
SPAS ₂	21.86	13.13	34.99
SPAN ₁	18.77	11.91	30.68
SPAN ₂	21.91	13.80	35.71
SP ₁	16.94	10.96	27.90
SP ₂	18.21	11.85	30.06
AS ₁	15.25	8.75	24.00
AS ₂	17.17	9.54	26.71
Control	9.55	8.19	17.74
'F' Value for the Treatments	147.17***	148.34***	108.41***
C.D. at the 5% Level	0.767	0.485	1.204

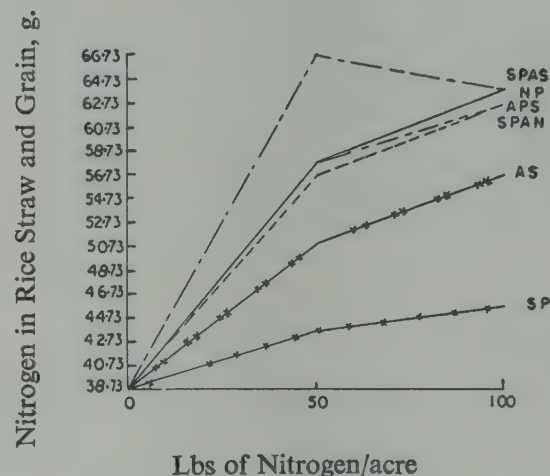


Fig. 19

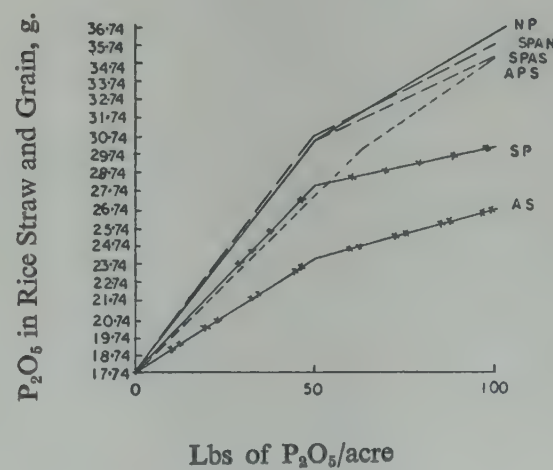


Fig. 20

TABLE 4—UPTAKE OF NITROGEN BY RICE PLANTS, G./PLOT
(Each figure represents an average of two replicates.)

Treatments	Rice Straw	Rice Grains	Straw + Grains
N ₁	31.98	25.32	57.30
N ₂	34.73	28.59	63.32
APS ₁	29.16	27.06	56.22
APS ₂	33.66	29.01	62.67
SPAS ₁	32.14	28.50	56.64
SPAS ₂	34.65	29.21	63.86
SPAN ₁	30.97	26.36	57.33
SPAN ₂	33.92	28.53	62.45
SP ₁	21.17	21.98	43.15
SP ₂	21.96	23.31	45.27
AS ₁	25.86	25.06	50.92
AS ₂	30.26	26.15	56.41
Control	18.53	20.20	38.73
'F' value for the Treatments	305.18***	65.50	177.19***
C.D. at the 5% Level	1.309	1.052	2.294

ments at both 100 and 50 lbs. levels. Unlike the case of nitrogen uptake, superphosphate treated plants took up more phosphorus at both the levels than the ammonium sulphate treated ones. Control plants were the poorest in this respect.

The above observations indicate that in the case of paddy there is little difference in fertilizer values of nitrophosphate, superphosphate-ammonium nitrate, superphosphate-ammonium sulphate and ammonium phsopahate sulphate under our soil and climatic conditions.

Acknowledgement

The authors' thanks are due to Dr. K. R. Chakravorty, General Manager, and Sri A. K. Roy, Addl. Superintendent, P and D Division for their keen interest in this work. Thanks are also due to Sarbasri B. P. Roy, S. Roy, B. N. Singh, and P. K. Chakravorty for their sincere help at different stages.

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Interaction between Humic Acid Fraction of Soil and Urea

By

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An attempt has been made to study the nature of interaction between soil humic acid and urea. Urea forms an addition complex with humic acid resulting in a decrease in exchange capacity and increase in pH. The complex formation takes place rapidly with increase in temperature and urea concentration but relatively slowly and progressively at room temperature.

Recently urea and humic acid mixtures are being prepared to find their suitability as fertilizers. Nakajima and Tikinami¹ prepared a powdered urea humic acid composite by evaporating in vacuo a mixture of acetone solution of humic acid and methyl alcohol solution of urea at room temperature. Nakajima et al² also prepared granulated urea humate from a mixture of dried humic acid and urea (10 : 90). Dragunova³ and coworkers reported that humic acids were soluble in 5M urea at 50°C. They presumed that it is an addition reaction of humic acids, urea and water. According to them, acid amides dissolve humic acids apparently forming addition products. Humic acids have been found reactive with other amino compounds. Thomson⁴ obtained resinous products by condensing humic acid, obtained from coal, with ethylenediamine, trimethylenediamine or hexamethylenediamine. In the present communication, our interest is to find the nature of interaction between urea and soil humic acid (containing humatomelanic acid) and also to study the effect of concentration, temperature and time on this process.

Experimental

The humus was extracted from a sample of black cotton soil (Amaravati, Maharashtra) by treating it with 0.5N Na₂CO₃. The mixture was heated to 50°C for few hours and allowed to settle for 48 hours. The supernatant liquid containing sodium saturated humus was siphoned off. It was then filtered carefully and the filtrate was coagulated with a little excess

of hydrochloric acid. The coagulum was redissolved in sodium carbonate solution, filtered and the filtrate was coagulated again with hydrochloric acid. The process was repeated for a number of times and the coagulum was finally electro dialysed.

The pH of a 0.200 per cent suspension of humic acid thus obtained was found to be 3.48. A second suspension of humic acid containing 0.180 per cent had a pH of 3.62.

20 ml. mixtures of urea and humic acid with varying concentrations of urea were kept in a number of bottles in a thermostat which was carefully regulated at 25°, 35° and 45°C ($\pm 0.02^\circ$). The mixtures were heated with constant stirring for five hours and kept in the refrigerator before potentiometric titrations were made. The titrations were carried out by means of a Philips PR 9403 pH meter at 25°C using 0.04N ammonium hydroxide and 0.05N sodium hydroxide solutions as titrants.

Results and Discussion

Urea has a tendency to form adduct with a number of compounds. With the help of its two amino groups, urea is capable of forming clathrates or channel compounds with long chain molecules⁵. It has been fairly established that humic acids are macromolecules of heteropoly condensates like the lignoproteinates, polyuronides, clay-proteins⁶, etc. The relatively high exchange-capacity of humic acids is due to residual COOH and OH groups. It is expected that these groups

will take part in the adduct formation with urea. Now if urea is linked up with these groups, the available hydrogen of humic acid will be less and hence an increase of pH as well as a decrease in exchange capacity are to be expected. These have been actually observed in our experiments done under a variety of conditions.

Effect of Concentration of Urea: The results given (Table 1) show that at constant temperature (25°C) pH of the urea and humic acid mixtures increases from 3.48 to 4.40 as the concentration of urea is increased up to 3M, the reaction time being two hours. An increasing interaction with urea concentration is thus indicated.

TABLE 1

Concentration of Urea, moles/l.	pH
0.0	3.48
0.5	3.78
1.0	3.95
2.0	4.20
3.0	4.40

Effect of Temperature: It will be observed from Fig. 1 and Table 2 that at a given concentration of urea and a reaction time of 5 hours the interaction with humic acid, as judged from the rise of pH, increases with increase of temperature.

Effect of Time: The reaction takes place slowly but progressively with time. pH of the mixture of humic acid and urea increases from 5.20 to 6.44 as the reaction time is increased from 96 to 432 hours (vide Table 3) at 25°C.

From these observations, it is apparent that the reaction time plays an important role in the complex formation between urea and humic acid. If urea, even in small concentration, is mixed with humic acid and the mixture is kept at ordinary temperature for a very long time, complex formation will take place. This is important from the practical point of view. It may be presumed that when urea is applied as a fertilizer, a portion of it is gradually fixed by soil organic matter through complex formation. Depending on the stability of these complexes, loss due to drainage by water may be prevented.

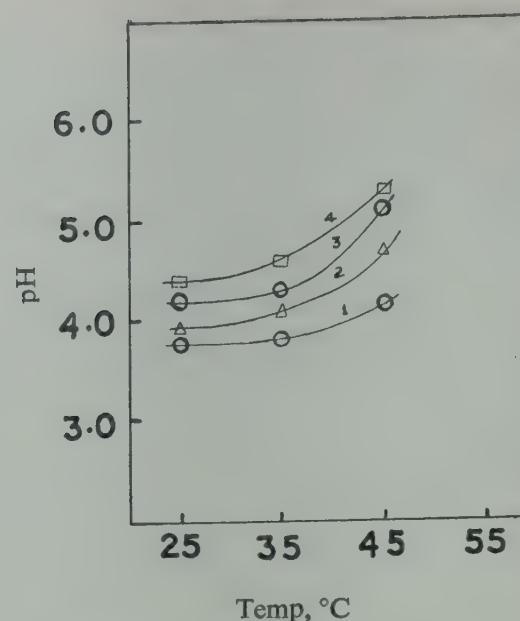


Fig. 1—Interaction between Urea and Humic Acid at Different Temperatures

1. Humic Acid (HA) in 0.5 M Urea;
2. HA in 1.0 M Urea
3. HA in 2.0 M Urea
4. HA in 3.0 M Urea

TABLE 2

Temperature, °C	Concentration of Urea, moles/l.	pH
25	0.5	3.78
	1.0	3.95
	2.0	4.20
	3.0	4.40
35	0.5	3.80
	1.0	4.10
	2.0	4.30
	3.0	4.60
45	0.5	4.15
	1.0	4.68
	2.0	5.10
	3.0	5.30

TABLE 3

Reaction time, hr	pH	Concentration of Urea, moles/l.
96	5.20	3.0
120	5.25	"
144	5.43	"
264	5.78	"
336	6.12	"
432	6.44	"

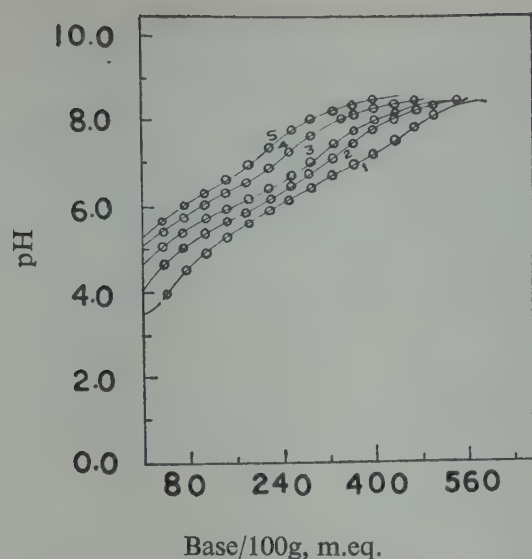


Fig. 2—Titration of Urea-Humic Acid Mixtures (heated to 45°C for 5 hr.) with Ammonium Hydroxide

1. Humic Acid (HA) in water alone; 2. HA in 0.5 M Urea; 3. HA in 1.05 M Urea; 4. HA in 2.0 M Urea; and 5. HA in 3.0 M Urea

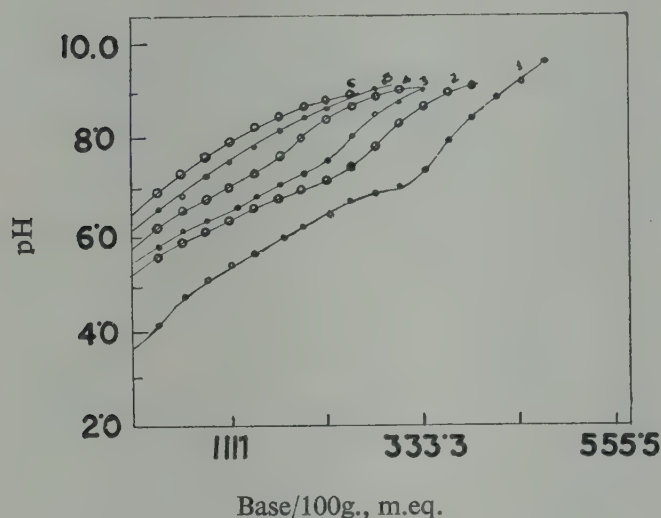


Fig. 3—Titration of Urea-Humic Acid Mixtures with Sodium Hydroxide

1. Humic Acid (HA) in water alone; 2. HA in 3 M Urea after 96 hr.; 3. HA in 3 M Urea after 144 hr.; 4. HA in 3 M Urea after 264 hr.; 5. HA in 3 M Urea after 336 hr.; and 6. HA in 3 M Urea after 432 hr.

Effect on Exchange-Capacity of Humic Acid and Stability of the Complex: Figs. 2 and 3 represent the titration curves of urea-humic acid mixtures obtained by increasing urea concentration and time of interaction of the mixtures with 0.04N ammonium hydroxide and 0.05N sodium hydroxide respectively. It will be observed that the milliequivalents of ammonium hydroxide and sodium hydroxides required to raise the pH of humic acid to a given value decrease with increasing complex formation. In other words, the neutralizable acidity of humic acid decreases due to complex formation with urea because of the involvement of—COOH and—OH groups in complex function. These titrations also indicate that the complex is fairly stable even at high pH's.

Acknowledgements

The authors' thanks are due to Dr. K. R. Chakravorty, General Manager, for his keen interest in the present investigation.

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Corrosion of Distillation Equipment in a Benzol Plant

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Studies have been carried out on the corrosion of mild steel equipment in the rectification still in the benzol recovery section of the coke oven plant at Sindri. A suitable mixture of hexamine, ammonia and acetone (or ethyl alcohol), added as inhibitor to the crude benzol, has been found to reduce the corrosion rate to a very low value.

In the Sindri by-product coke oven plant, the bubble trays in crude benzol rectification still have to be opened up frequently and cleaned of rust deposits which fall from mild steel dephlegmator coils and cause heavy pressure drops. On the condenser side, the mild steel cooler condenser tubes develop leaks. An examination of these tubes showed scale formation, tuberculation, and pitting on the water side; the oil side had also undergone severe corrosion. The present study is concerned with benzol side corrosion.

The corrosion of distillation equipment in benzol plants is a major problem whether caused by the formation of sulphur dioxide or sulphuric esters during rectification or by cooling water. Todd¹ is of the view that the corrosion of condensers in the refining still is mainly caused by sulphur dioxide produced by the decomposition of bodies formed during acid washing processes and which remain in solution in the washed benzol. Brooks and Humphrey² state that benzol after acid treatment contains, besides polymerized products, neutral sulphuric esters of the type $\begin{matrix} \text{RO} \\ \text{RO} \end{matrix} > \text{SO}_2$ which

decompose during subsequent distillation yielding tarry residues and sulphur dioxide. The quantity of esters formed is inversely proportional to the amount of acid used but increases with the strength of the acid. The composition of crude benzol as well as the temperature and time of contact with acid had also effect on corrosion rate. Claxton and Hoffert³ state that cyclopentadiene and dicyclopentadiene appear to be the substances primarily responsible for the production of sulphur dioxide in the still. Where a forerunning frac-

tion can be taken from a fresh crude, the cyclopentadiene having a boiling point of 42°C will be removed and will thus considerably reduce the production of sulphur dioxide during subsequent refining.

In general, the various preventive measures for minimizing the corrosion of the distillation equipment fall into the following broad categories:—(1) Modification of the refining process so as to have minimum production of sulphur dioxide during distillation; (2) neutralization of the corrosive vapours in the still; (3) change-over to a more corrosion-resistant material; (4) use of some material in the vapour stream immediately before the zone of corrosion which is readily corroded and is easily replaceable; and (5) use of vacuum distillation.

Various methods falling under the above categories are employed for corrosion control in the industry depending mainly on the economics, those falling under groups (1) and (2) being more in practice. So far as the modification of the refining processes is concerned, the taking off of forerunnings from freshly made crude benzol will effect considerable improvement in most cases, besides allowing the use of a weaker acid wash. The neutralization of the acid vapours has been used widely in petroleum industry for a considerable time. Wilson and Bahlke⁴, Birch⁵, Thornton⁶, and Malecki⁷ have all advocated the use of soda lime, soda ash, or caustic soda in the still for the neutralization of acid vapours. But opinions differ on the use of the particular alkali. Evans⁸, Todd¹ and Hamilton⁹ have all advocated the use of ammonia, in contrast to the other alkalis, which may be fed conveniently to

the still or other parts in gaseous or liquid form. Hoffert and Claxton¹⁰ strongly deprecate the use of caustic soda in the still, since it readily produces mercaptans; soda ash is less objectionable. They¹⁰ also advocate the use of ammonia. The main idea underlying these neutralization steps is to obtain a neutral distillate. Nave¹¹ reports, however, that when severe acid washing is done, corrosion is not checked by neutralization with any alkaline substance.

The present investigations were undertaken to find out a suitable remedy for the corrosion of mild steel dephlegmater coils and cooler condenser tubes either by removal of forerunnings or by the addition of suitable inhibitors inside the still.

Experimental

Test coupons $6.2 \times 1.0 \times 0.2$ cm. cut from mild steel sheets* were used in all the experiments. A 6 mm. diam. hole was drilled in each of them. Their surfaces were prepared by '0' emery paper and the exact measurements of the area were made by callipers. They were then degreased in boiling toluene, washed with alcohol, dried and weighed. After the experiment, the adhering corrosion product was removed and the coupons were treated with inhibited acid¹², degreased, dried and weighed. The loss in weight was recorded as mg./sq. dm./day.

The coupons were hung by glass hooks passing through the holes drilled in them. In all the experiments washed crude benzol had been used. 800 ml. of washed crude benzol were taken in the flask and heated in an oil bath (Fig. 1). The distillate fell in the receiver in the form of drops at the top of the test coupon, thus finally wetting it before falling down. The rate of distillation was so adjusted that 6 hours were taken for attaining a vapour temperature of 160°C at the top of the distilling flask as indicated by thermometer (T_1), and about 700 ml. of the distillate was collected during that period. The vapour temperature (160°C) had been selected so as to make the conditions more severe than in the plants. At the end of 6 hours when the vapour temperature was attained, stopcocks A and B were opened. Air was sucked in for about 10 minutes, so that any sulphur dioxide or other gases left in the distillation chamber were sucked in the receiver and thus came in contact with the test coupon.

By this testing device all gases evolved from the benzol came in contact with the test coupon either in

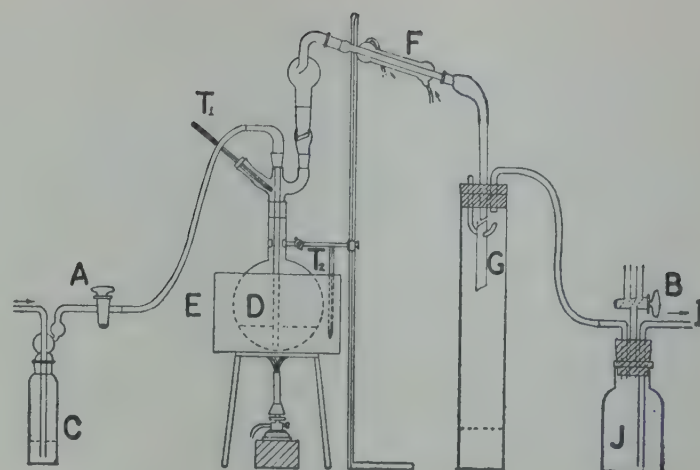


Fig. 1

- A — Stop Cock
- B — Stop Cock
- C — Bubbler Containing 10% Caustic Soda Solution
- D — Round Bottomed Distillation Flask
- E — Oil Bath
- F — Water-cooled condenser
- G — Test coupons
- H — Measuring Cylinder to Receive Distillate
- I — To Suction Pump
- J — Bottle with Dual Connexion to Atmosphere and Suction
- T_1 — Thermometer for Recording Vapour Temperature
- T_2 — Thermometer for Recording Oil Bath Temperature.

gaseous form or as absorbed in the distillate itself. The results had been very reproducible. Each result reported is an average obtained from at least two separate experiments.

For the estimation of sulphur dioxide evolved during distillation, the method of Dummett¹³ had been followed. All the chemicals used were of A.R. quality. Hexamine had been added in the solid form. All the substances tried as inhibitor had been added to the distilling still along with benzol sample.

Results and Discussion

In Table 1 are given the corrosion rates of mild steel in some benzol samples with different sulphur dioxide contents which are evolved during distillation. The results clearly indicate that the corrosion of mild steel increases as the sulphur dioxide content increases. A systematic pattern was followed in experiment Nos. 1 to 7, viz. the corrosion rate increasing with the corresponding increase in the sulphur dioxide content. The results in experiment Nos. 8 to 10 also show a similar pattern but independent of the previous one. These results indicate that although sulphur dioxide is the major corrosive ingredient, some other materials also play significant roles in influencing the corrosion rate. The sulphur dioxide might be liberated either by the decomposition of neutral sulphuric ester or cyclopentadiene.

* Specification I.R.S.M. 16/49 manufactured by Tata Iron & Steel Co., Ltd.

TABLE 1—CORROSION RATES OF MILD STEEL WITH DIFFERENT BENZOL SAMPLES GIVING OFF DIFFERENT AMOUNTS OF SULPHUR DIOXIDE

Expt. No	Amount of SO ₂ , mg/1000 ml. of Benzol	Corrosion Rate, mg/sq. dm./day
1	24.4	6.8
2	30.1	15.8
3	94.1	290.2
4	113.7	430.0
5	221.3	466.5
6	232.3	523.0
7	244.0	526.0
8	333.0	358.3
9	440.8	468.6
10	444.5	487.3

The effect of the removal of forerunnings and of the addition of inhibitors is shown in Table 2. The fore-

runnings were removed up to 70°C and 75°C from benzol sample No. 1 and up to 75°C from sample No. 2 but the samples were still corrosive, although corrosion rates were reduced to a considerable extent. Thus the removal of forerunnings as a means of checking corrosion was not very effective in these cases. An attempt was, therefore, made to find out substances which when added to the distilling still with the feedstock will check the corrosion of mild steel, whether caused by neutral sulphuric esters, cyclopentadiene, certain polymerized products or any of the numerous other substances present in the washed crude benzol.

The benzol samples 3, 4 and 6 (Table 2) relatively low in sulphur dioxide content, show comparatively high corrosion rates—the rates being quite unrelated to their respective sulphur dioxide contents. These samples were intentionally kept for some time after collection from the plant. Though their sulphur dioxide contents

TABLE 2—CORROSION RATES OF MILD STEEL IN BENZOL IN PRESENCE/ABSENCE OF INHIBITORS

Benzol Sample	Expt. No.	Amount of SO ₂ mg./800 ml. of Benzol					Corrosion Rate, mdd.	Remarks
			Ethyl Alcohol, ml.	Hexamine Molar Ratio of SO ₂ : Hexamine	Ammonia Molar Ratio of SO ₂ : NH ₃	Acetone, ml.		
1	2	3	4	5	6	7	8	9
1	(a)	90.92	—	—	—	—	430.0	
	(b)	90.92	—	—	—	—	419.3	after discarding forerunnings up to 70°C.
	(c)	90.92	—	—	—	—	168.3	after discarding forerunnings up to 75°C.
2	(a)	74.08	—	—	—	—	290.2	
	(b)	74.08	—	—	—	—	83.0	after discarding forerunnings up to 75°C.
3	(a)	100.2	—	—	—	—	631.3	
	(b)	100.2	—	1:1	—	—	129.6	Benzol Samples 3, 4 & 6 are samples which had been aged for some time.
	(c)	100.2	—	1:10	—	—	56.6	
	(d)	100.2	—	1:20	—	—	7.7	
4	(a)	84.7	—	—	—	—	602.7	
	(b)	84.7	—	1:10	—	—	59.6	
	(c)	84.7	—	1:20	—	—	39.2	
	(d)	84.7	—	1:30	—	—	6.4	
	(e)	84.7	—	—	1:40	—	217.8	
5	(a)	177.0	—	—	—	—	466.5	
	(b)	177.0	—	1:20	—	—	78.2	
	(c)	177.0	—	1:30	—	—	18.2	
	(d)	177.0	—	—	—	5.0	388.8	
	(e)	177.0	—	—	1:20	5.0	215.5	
	(f)	177.0	—	1:20	—	5.0	17.0	
	(g)	177.0	—	1:20	1:20	5.0	No corrosion	

TABLE 2 (Contd)

Benzol Sample	Expt. No.	Amount of SO_2 mg./ 800 ml. of Benzol	Ethyl Alcohol, ml.	Hexamine Molar Ratio of SO_2 : Hexamine	Ammonia Molar Ratio of SO_2 : NH_3	Acetone, ml.	Corrosion Rate, mdd.	Remarks
1	2	3	4	5	6	7	8	9
6	(a)	266.4	—	—	—	—	1293.0	Initial corrosion rate of mild steel was 358.3 mdd. before ageing of the sample.
	(b)	266.4	—	1:3	1:14	5.0	40.2	
	(c)	266.4	—	1:4	1:14	5.0	13.2	
	(d)	266.4	—	1:4	1:3	5.0	46.7	
	(e)	266.4	—	1:4	1:5.5	5.0	16.6	
	(f)	266.4	—	1:4	1:5.5	1.0	22.8	
	(g)	266.4	—	1:4	1:4	4.0	7.5	
7	(a)	192.0	—	—	—	—	526.6	
	(b)	192.0	—	1:4	1:8	2.0	39.2	
	(c)	192.0	—	1:4	1:8	3.0	24.6	
	(d)	192.0	—	1:4	1:8	4.0	9.6	
	(e)	192.0	—	1:4	1:8	5.0	9.2	
	(f)	192.0	—	1:4	1:4	4.0	6.9	
	(g)	192.0	—	1:4	1:20	4.0	13.7	
	(h)	192.0	—	1:4	—	4.0	124.9	
8	(a)	345.6	—	—	—	—	468.6	
	(b)	345.6	—	1:4	1:4	4.0	6.2	
	(c)	345.6	—	1:4	1:3	4.0	12.4	
	(d)	345.6	—	1:4	1:5	4.0	11.9	
	(e)	345.6	—	1:4	1:4	3.0	24.9	
	(f)	345.6	—	1:4	1:4	5.0	11.5	
	(g)	345.6	—	1:3	1:4	4.0	9.9	
	(h)	345.6	—	1:5	1:4	4.0	7.0	
9	(a)	352.6	—	—	—	—	487.3	
	(b)	352.6	—	1:4	1:4	4.0	No corrosion	
	(c)	352.6	—	1:4	1:4	3.0	23.6	
	(d)	352.6	—	1:4	1:4	5.0	13.8	
	(e)	352.6	—	1:4	1:4	2	No corrosion	These sets of experiments were done with 400 ml. of benzol sample, other conditions being same.
	(f)	352.6	—	1:4	1:4	2.5	15.0	
	(g)	352.6	—	1:4	1:4	1.5	25.2	
	(h)	352.6	5.0	1:4	1:4	—	9.8	
	(i)	352.6	4.0	1:4	1:4	—	No corrosion	
	(j)	352.6	3.0	1:4	1:4	—	20.9	

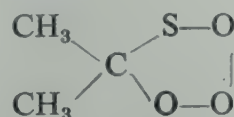
remained the same after storage, their corrosiveness increased considerably. Sample 6 had an initial corrosion rate of 358.3 mdd. which later on increased to 1293 mdd. after storage.

Neutralization with ammonia was tried as a means of minimizing the corrosion, but even 40 moles of ammonia per mole of sulphur dioxide could only reduce the corrosion from 602.7 to 217.8 mdd in case of sample 4.

Hexamine was next tried with benzol sample 3. It will be observed that as the quantity of hexamine increases, corrosion rate goes down and with 20 moles of hexamine per mole of sulphur dioxide the corrosion is reduced to 7.7 mdd from an initial corrosion rate of 631.3 mdd. But with sample 4, with an initial corrosion rate of the same order as sample 3, 30 moles of hexamine per mole of sulphur dioxide is required to reduce the

corrosion to the same extent as in sample 3. With sample 5, on the other hand, having an initial corrosion rate of 466.5 mdd, which is much less than that with samples 3 or 4, the corrosion is not checked to the same extent as in samples 3 and 4, even by the addition of 30 moles of hexamine per mole of SO_2 . These results clearly indicate that ammonia alone is not able to check corrosion by benzol, while hexamine, though very effective, is not able to check it with equal efficiency in all the cases.

Schulze¹⁴ has stated that acetone dissolved sulphur dioxide forming a complex of the following type.



Experiments were, therefore, performed with benzol samples [Sample 5, (experiments d, e, f, g) (Table 2)] to study the inhibitive action of acetone alone and in combination with hexamine and ammonia separately and also in combinations in which all three were present. The results show that acetone alone or in combination with either hexamine or ammonia reduces the corrosion rate but fails to check it completely. A combination of 5 ml. of acetone and 20 moles of hexamine per mole of sulphur dioxide behaves in the same way as 30 moles of hexamine per mole of sulphur dioxide (experiments c and f with sample 5, Table 2). But a combination of hexamine and ammonia, each 20 moles per mole of sulphur dioxide and 5 ml. of acetone is able to reduce corrosion rate to nil from an initial rate of 466.5 mdd. (experiment g with sample 5).

An attempt was next made to find out the optimum amounts of these additives and to find out whether any co-relation existed between the quantity of these additives with the total sulphur dioxide evolved during distillation and the volume of benzol. Different proportions of hexamine, ammonia and acetone were tried together. The results with sample 6 (Table 2) show that a mixture of hexamine and ammonia each four moles per mole of sulphur dioxide and 4 ml. of acetone is able to reduce the corrosion rate to a very low value—from an initial rate of 1293.0 to 7.5 mdd. Further experiments were carried out to evaluate the effectiveness of the combination of hexamine, ammonia and acetone with fresh crude benzol samples. Results with sample 7 (Table 2) confirm the findings obtained with sample 6. A mixture of 4 ml. of acetone, hexamine and ammonia, where the quantities of the latter two ingredients were in molar ratio of 4 with respect to sulphur dioxide content, reduces the corrosion rate from 526.6

to 6.9 mdd. Any change in the amounts of hexamine and acetone from the optimum values increases the corrosion rate. Further experiments with sample 8 (Table 2) confirm these findings: in this case hexamine and ammonia each in molar ratio of 4 with respect to sulphur dioxide content and 4 ml. of acetone are able to bring down the corrosion rate from 468.6 to 6.2 mdd. Any change in the quantities of hexamine, ammonia or acetone from these optimum values increases the corrosion rate.

In all these experiments with different benzol samples—whether fresh or stored, highly or mildly corrosive—co-relation has been obtained with the quantities of ammonia and hexamine and that of sulphur dioxide evolved from the benzol but the quantity of acetone requirement in each case was only 4 ml. irrespective of other characteristics of benzol. To establish the quantity of acetone required for best inhibition, further experiments were carried out with sample 9. The results of experiments a to g (Table 2) show that 800 ml. of benzol required 4 ml. of acetone, while 400 ml. required only 2 ml. of acetone for completely eliminating corrosion, in combination with 4 moles of hexamine and ammonia each per mole of sulphur dioxide content.

Any change in the quantity of acetone increased the corrosion rate. Hence, it can be inferred that for inhibiting the corrosion caused by benzol, the quantities of hexamine and ammonia are related to the total sulphur dioxide content, while the quantity of acetone is related to the total volume of the benzol.

According to Saussure¹⁵ ethyl alcohol absorbs sulphur dioxide. Carius¹⁶ also reported that a saturated solution of sulphur dioxide in alcohol dissolves higher volumes of sulphur dioxide depending upon temperature. Experiments were, therefore, conducted to find out if ethyl alcohol was also effective like acetone in combination with hexamine and ammonia in preventing the corrosion by benzol.

Experiments h, i, j with sample 9 (Table 2) show that 4 ml. of ethyl alcohol with 4 moles of hexamine and ammonia each with respect to the sulphur dioxide content is as effective as acetone in the elimination of corrosion by benzol. Any change in the quantity of alcohol increases the corrosion.

Conclusion

The above results, therefore, show that by adding hexamine, ammonia and acetone (or ethyl alcohol) in the distillation still together with benzol, corrosion of mild steel can be completely checked.

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On the Selection of Synthesis Gas Compressor for Ammonia Plants

By

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The present trend in world fertilizer technology is towards larger single stream plants—especially ammonia plants. As a development of this trend, centrifugal compressors for synthesis gas compression are playing an increasingly prominent role. The *pros and cons* of use of centrifugal and reciprocating compressors for synthesis gas compression, their applicability and the economics of their use under Indian conditions have been discussed. A graph has been developed for a 600 te/day ammonia and a 1000 te/day urea plants to help the selection of the type of compressor depending upon costs of power and steam.

For quite some time past the trend in the advanced countries has been to build heavy chemical plants in single streams with as high a capacity as permitted by technological and engineering considerations put into individual equipment. Several advances in diverse fields have contributed to the sizes and capacities of fertilizer plants—especially ammonia production units—as are by and large being planned, designed and installed abroad. In such units, the significant features have been the availability of cheap hydrocarbon feedstock in bulk, development of processes for conversion of this feedstock to synthesis gases under high pressures which enable building in large throughput capacities into compact size single equipment and the evolution of high speed centrifugal compressors, specially suited for handling large volumes of gas. Developments in the modern fertilizer technology have come from better metallurgical materials and perfection of engineering technique for building in pressure units for corrosive and rigorous operating applications, successful commercialization of several processes formerly considered experimental and application of mechanical equipment developed in allied fields, like space rocketry, etc.

Types of Compressor

A critical item among ammonia synthesis equipment is the compressor machine. The reciprocating type, traditionally used in this application, would require multiple units to handle gas volumes in excess of equivalents of 300 te/day. With a centrifugal machine, the

minimum economic throughput comes at a level in excess of 550 te/day of ammonia. From the published data on the new fertilizer plants that will be erected in India in near future, it would appear that the capacity of the major ammonia units planned will be standardized at 600 te/day of ammonia. The following discussion has been restricted to conditions at the 600 te/day of ammonia capacity level.

Centrifugal vs Reciprocating Compressor

Centrifugal compressors with barrel-type casings had already been in use in the petroleum industry for the compression of hydrocarbon gases and air. With light petroleum hydrocarbons coming into prominence as a promising feedstock for ammonia and the consequent entrance of the oil industry into the picture, it was natural that centrifugal compressors should also be tried in the fertilizers industry.

The use of centrifugal compressors for synthesis gas compression has had to contend with two main problems on adaptation: one is the comparatively low density of the synthesis mixture which makes development of pressures by conversion of kinetic to potential head a problem of considerable magnitude; the other was the high pressures and low absolute volumes of gas at the ultimate stages of conventional conversion process which brought in mechanical problems in devising suitable rotors with narrow passages for the higher pressure stages. Both of these have been nearly overcome with the result that almost all the new plants

where the single stream capacity is more than 550 te/day of ammonia have opted for centrifugal compressors.

Because of the vigorous sponsorship which the idea of use of centrifugal types has received, an impression has been created in this country that a plant which cannot use such a compressor is antiquated. Since such a generalization may lead to erroneous decisions, there is justification for a detailed analysis in depth on the *pros and cons* of centrifugal compressor application taking the peculiar Indian conditions into account. A cautious approach to this problem is called for since it has often been found that what is ideal for a developed country does not necessarily always fit in with circumstances in another country where technological resources are limited. In this country, for instance, the full cognizance of the availability of foreign exchange, the future requirements of spare parts, facilities for quick maintenance services, possibility of local manufacture of similar equipment or components thereof now or in the near future, etc. have to be taken. The developed countries do not have to worry about these.

Performance Characteristics: Centrifugal compressors are essentially high speed rotary machines essentially fit for handling large volumes of gas. Because of the high speed and running characteristics, compact units can be built for large capacities and they fit in very well with the massive single-stream concept which is now the trend. For instance, for an application on a 600 te/day ammonia plant, at least two reciprocating machines will have to be commissioned to do duties which a single centrifugal can tackle. It is claimed that centrifugals, being pulsation-free and essentially well-balanced in operation as well as compact, would require a much lower outlay on foundation, interconnecting pipes between multi-stages, etc. This claim appears reasonable.

Because of the high speed operation, centrifugal compressors are best coupled with high speed prime movers, like steam turbines. This is of particular advantage in integrating energy usages in the latest light hydrocarbon-based units, in the sense that the designs aim at heat recovery from the process to produce high pressure steam which is used for drives as well as for subsequent process feed or heating applications. On the other hand, reciprocating machines, especially for heavy duties envisaged in ammonia plants, are normally standardized for operation at much lower speeds usually around 300 rpm. This is one of the factors which affect the size and weight of the machine. Because of their slower speed turbine drives cannot be easily adopted for reciprocating machines. From the point of view of thermodynamic

efficiency, reciprocating machines (perhaps due to their slower speed of operation and better cooling facilities provided both in inter-stage as well as at the compression stage) have an edge over the centrifugal ones, the difference being anywhere between 10 and 5 per cent depending upon the size of operation. Where the power for drives is derived from thermal sources, it may, however, be argued that the overall efficiency reckoned on the basis of fuel requirements for the compression duty may equate as between the two types, because a motor drive involves two stages of energy transformation, first to raise steam and generate power, and then to transmit and apply the power to the drives—and the losses incurred at both these stages would make up for the intrinsically lower efficiency secured in direct drives on centrifugals. But where power is available cheap, say from hydroelectric sources, the differences may give a pronounced advantage to the reciprocating machine.

The centrifugal type has to operate with close running clearances with a total avoidance of rubbing contacts. The mechanical design and finish have to be of a much higher order especially since the temperature attained inside the casing is much higher than that normally in a reciprocating machine, which calls for very careful design and execution. On the other hand, the machine, once in operation, generally gives a continuous trouble-free run with little maintenance attention over fairly long periods as wear and tear are limited. Any accidental damage, however, would involve repair work, which is more complicated and skilled than for a reciprocating machine. A reciprocating machine, on the other hand, has quite a number of wearing surfaces as well as parts subject to alternating and fluctuating loads. Wear and tear and failure of parts are more frequent but repairs are also within the range of skill and facilities developed in this country. The use of multiple units which becomes essential for higher capacities also has the effect of restricting the overall production losses due to downtime and may compensate to some extent for the more frequent attention needed.

In the light of the above, the claim that use of centrifugals improves annual throughput of a plant requires a careful scrutiny. For instance, it is claimed that downtime on a centrifugal compressor may be about 50 per cent of that for the reciprocating type. This, however, has yet to be established over a period of years in actual practice. This argument, however, is often used as the basis for a claim that the streams efficiency of the centrifugal machine-based ammonia plant will be higher than for a plant based on a reciprocating machine. Here the compressor availability is confused with plant avail-

ability. A regular check on the overall regular maintenance schedule for a typical ammonia plant with the latest design concepts will indicate that over a period of years, in comparison with the essential down-time for catalyst change, boiler inspection, preventive maintenance, etc., compressor availability, by itself, ceases to be a critical factor as far as a single-stream plant is concerned. Any marginal advantages, either way, will not tip the scales decisively in favour of one case or the other.

There are, however, two factors which weigh considerably in favour of the reciprocating compressor. The first is better amenability to load variations. This is due to both the necessity for the multiple units (which straightway allows for fractional cuts on loads by taking particular units out of line) as well as facilities which can easily be built into the reciprocating machines for infinite variation in volumetric throughput by devices like clearance pockets, regulators for valve opening, etc. These enable ammonia plant operation to be synchronized more easily with levels of operation on subsequent ammonia processing units.

The other factor is the capabilities of the reciprocating machines to adapt themselves to a much wider range of discharge pressures independent of volumetric throughput. A lack of adaptability in this respect has been a serious limitation on centrifugals till recent times. Load variation permissible is of the order of 65 per cent and has to be accomplished mainly by variation in drive speeds, a procedure which incidentally affects adversely the efficiency. Any wider variation has necessarily to be accommodated by the wasteful method of bypassing part of the discharge stream by throttling back to suction. Moreover, since the power for drives are derived from steam generated in plant, and the quantum of steam available will, in turn, be proportionately reduced because of the lower loads, the question of balancing steam demand and supply within the unit will also present complications. Where power for drives are independently arranged for, as in the case of the reciprocating machines, these complications would not come in.

The second factor, viz. the linking up of possible discharge pressures with volumetric throughput had brought about the necessity for a good deal of improvisations on the synthesis unit as such. For instance, till a few months back, the available models of centrifugal compressors for a 600 te/day ammonia plant could develop a discharge pressure of only up to 150 kg/cm² approximately. As the discharge pressures of the centrifugal compressor were lower, the synthesis

of ammonia had to be arranged also at a commensurately lower pressure which unfortunately represents a retrograde departure from the optimum pressures for synthesis operation. Against this sponsors for some of the latest ammonia units point out that over the years ammonia synthesis has been done over a wider range of pressures from 150 to 1000 kg/cm² or above, and there could be no question of considering the synthesis section in isolation so long as the overall system has the advantages claimed. The argument is somewhat weakened by the fact that where a higher volumetric throughput permits a higher discharge pressure—such as, for ammonia plants with capacities 1000 te/day and above—designs are adopted to the maximum permissible pressure of operation dictated by the centrifugal machine. The use of lower synthesis pressures brings in a lower thermodynamic efficiency not only on the compression step—as compared to the performance of a reciprocating machine of identical range—but also on overall basis, as it puts up energy required for the synthesis mixture recirculation in the loop as well as for refrigeration to remove the product, ammonia. In other words, the over-all energy requirements for producing ammonia starting from raw synthesis gas at a given pressure and using systems optimally adapted for the centrifugal as well as for reciprocating machines respectively may work out marginally in favour of the latter.

Fortunately, fabrication techniques for the centrifugal machines have been improved during the last one or two years. Machines have now been developed by an Italian firm which would permit discharge pressures of the order of 250 kg/cm² even with gas throughputs equivalent to 600 te/day ammonia production. This would tend to remove one of the basic disadvantages of the centrifugal machines in ammonia synthesis operation.

On the operational side, temporary shut-downs may also pose problems with steam drives. Irrespective of the reliability of the centrifugal compressor, shutdowns are likely to occur due to other equipment or in other sections of the plant during which the compressor also may have to be stopped or kept idle. The steam turbine, if it has to be kept ready for operation in a short time, has to be kept rotating, by flooding steam continuously though at a much reduced rate than while in operation. Even this, according to some, is not a desirable method.

On the other hand, if shut-downs are of a longer duration one may have to stop the compressor and restart it when required. Both these operations take time as increase or decrease of the temperature of the

turbine, as a whole, has to be gradual and not rapid. The reciprocating machines on motor drive, on the other hand, give a much higher flexibility in operation in such contingencies.

Economics

It is often claimed that use of the centrifugal compressor would bring down investment costs on comparable capacity ammonia plants by about 10 per cent compared to use of reciprocating machines. These are generalizations which are rather difficult to verify. From data supplied by one of the leading firms in this field, on the compressor installation cost alone a saving on centrifugals over reciprocating machines, of the order of 2 to 3 per cent, was indicated. The point, however, cannot be very easily settled without access to a wide range of quotations for sets of machines for identical duties. Again, a comparison of costs on compressors alone could be misleading since the optimum process designs adapted to the use of centrifugal and of reciprocating compressors would not normally be the same. The comparison, therefore, has to be on the investments for the total installation.

From one set of quotations available, on this basis it would appear that the difference between investments for installations on either system is only marginal, if any, and of an order which would hardly justify a choice in favour of the cheaper one. Again, depending upon local conditions even these figures may change. It would be unwise to generalize on this aspect.

On the running and maintenance costs of the machines, again, local conditions may turn out to be a decisive factor. Reliable data on centrifugal machine performance over a sufficiently long period is not available, especially on the more advanced models being developed now. There is, however, little doubt that under present conditions the maintenance inventory for centrifugal machines installed in this country will be higher at least for some time to come. The maintenance of high speed centrifugal machines is a highly skilled job with some features which can generally be attended to in a well-equipped workshop rather than *in situ*. As a matter of fact, centrifugal compressor manufacturers often recommend a spare rotor to be kept for emergency substitution. These are all costly items which will lock up a considerable amount of working capital especially in consideration of delays in availability of foreign exchange, distance of the supplier from India, etc.

The effects of use of centrifugal compressors on production costs of ammonia have been analysed in

some detail. The versatility of centrifugal compressor to adapt itself to different drives has got an important bearing on the economics of ammonia and fertilizer production. Where power is cheap—regions like Kerala, Mysore and Punjab—or where steam is comparatively costly because the fuel, oil or coal, has to be brought in from a long distance as in Punjab, Maharashtra and Kerala—energy supplied as electric power is cheaper than that as steam. In those cases, power drives and hence reciprocating compressor-based fertilizer units are preferable because a reciprocating machine requires less energy than a centrifugal one. Where power is costly but steam is cheap because of low cost fuel—is regions like Bihar and W. Bengal—or where a cheap fuel is available for gas turbines—say in Assam and Gujarat—centrifugal machines are likely to give cheaper fertilizer.

Again any analysis of economics of fertilizer production with relation to synthesis gas compressors should not strictly be confined to ammonia plant alone. Ultimately, at least in India, the choice of a component equipment or a process should depend not only on its effect on ammonia plant alone, but on its effects on the cost of production of the end product, viz. the fertilizers. Just as a close integration of all facilities

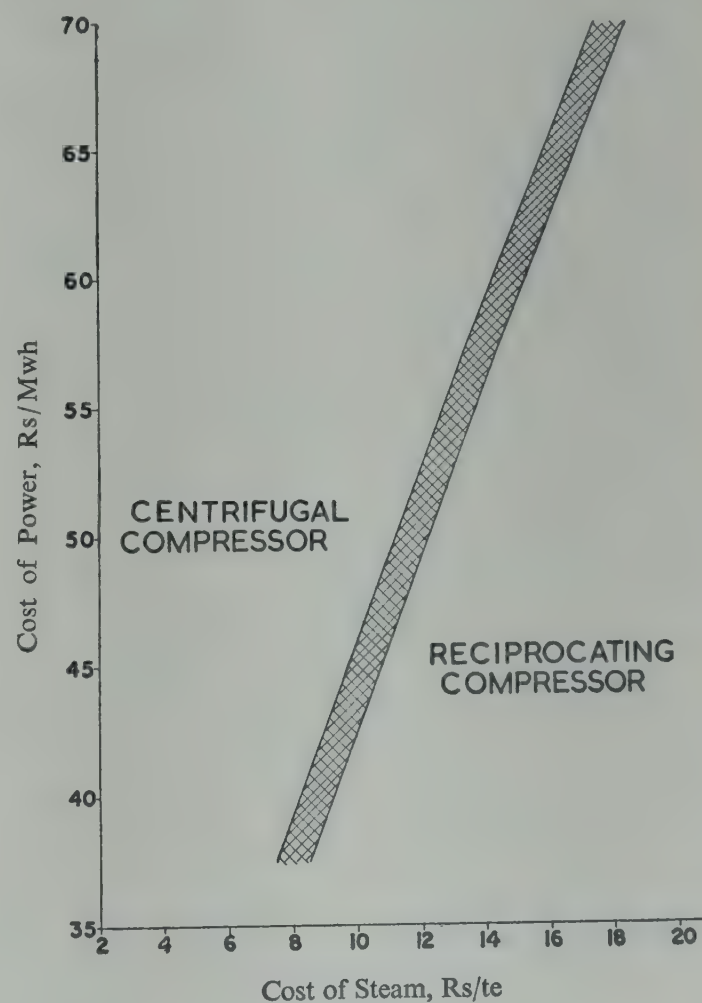


Fig. 1

within an ammonia plant helps to bring about cost optimization, a similar exercise covering the whole complex, starting from feedstock to the finished fertilizers embracing service facilities too, could influence the choice of the component unit. Such an exercise has been done with respect to an ammonia and urea plants of capacities 600 and 100 te/day respectively (Fig. 1). The zones where the particular compressor applications may come out more favourable are indicated (Fig. 1).

Conclusions

The application of centrifugal compressor in synthesis gas compression no doubt represents an advancement fitting in with the massive single-stream concept of ammonia production units now in vogue abroad. But these machines as well as the allied plants are all fairly pioneering ventures which have to prove their mettle on sustained operation for several years. When one accepts these concepts for the economies which are evidently claimed for them, one necessarily has to accept the risks of such a venture. While as a bold experiment one could accept the schemes for one or

two of the new installations, caution is called for in generalizing that without these machines no new plant is worth considering.

Also, plant capacities for particular locations should not be fixed on the basis of enabling centrifugal compressor application possible. Neither from the point of view of technology nor from investment and operating economies such a generalization appears warranted. Indeed one of the foreign firms, who have been pioneers in introducing the new ammonia process concepts for their own plants abroad, are reported to have decided to go in for the reciprocating type for the plant they propose to set up in India. The point is that dogmatism or unqualified acceptance of whatever is claimed as an advance abroad as of equal suitability or application to this country is an attitude which the objective planner should steer clear of. The aim and objective of planning should be kept always in view, especially the need for reliability and proven performance besides economies in putting up fertilizer units. Each location and situation has to be thoroughly analyzed before deciding on the techniques or equipment.

Preparation of a Light Oil Absorbent from the Still Bottom Oil in a Benzol Plant

By

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In most of the by-product coke-oven plants, light oil is recovered by scrubbing the coke-oven gas with a suitable wash oil. A large number of such absorbents, either of coal tar or petroleum origin, are known. In the present study, it has been observed that the oil from the bottom of the fractionating still for refining light oil products could yield an appreciable quantity of higher boiling fractions. A blend, prepared by mixing one part of 270-330°C fraction of the above still bottom oil with one or more parts of coal tar fraction 230-310°C, has been found quite suitable for scrubbing the light oil from the coke-oven gas.

Introduction

The recovery of light oil or benzol from coke-oven gas is carried out by suitable liquid or solid absorbents.¹⁻³ Although a large number of liquid absorbents have been recommended in literature, only a few have found extensive commercial utilization⁴. Among such absorbents either a coal tar or a petroleum oil fraction is usually employed, though the former has been used more widely. In Sindri Coke Oven Plant, benzol is recovered by scrubbing the gas with a high temperature coal tar wash oil. The absorbed crude benzol is recovered from the enriched wash oil by steam stripping and the regenerated wash oil is recycled in the process. The crude benzol, thus recovered, is successively washed with sulphuric acid and caustic soda and is then fractionated in stills to obtain refined and pure products. While the still bottom oils contain appreciable quantity of tar oils along with naphthalene, pitch, etc.

An exhaustive study of the different characteristics of the individual stills bottom oils has been made with the object of preparation of a suitable absorbent for the light oil.

Experimental Procedure

Materials: The following products from the benzol

plant of the coke oven plant were used for the present study: (a) Bottom oil of the fractionating still for refined light oil products, termed as S.B.O.₍₁₎, and (b) Bottom oil of the fractionating still for pure light oil products, termed as S.B.O.₍₂₎.

The following determinations were carried out:

(i) *Characteristics of the Still Bottom Oils:* A detailed study of the characteristics of the individual stills bottom oils was carried out (Table 1).

TABLE 1—CHARACTERISTICS OF STILL BOTTOM OILS OF
SINDRI COKE-OVEN BENZOL PLANT

Sl. No.	Properties	Still Bottom Oil of refined pro- ducts fractionating still	Still Bottom Oil of Pure products fractionating still
1.	Specific Gravity	1.078 at 40°C	0.868 at 30°C
2.	Specific Viscosity	5.4°E*at 45°C	0.94°E*at 30°C
3.	Distill over at °C (% by Vol.)		
	100	—	78
	180	2	96
	210	9	—
	230	24	—
	270	44	—
	330	84	—

*°E—Specific Viscosity Engler

(ii) *The Characteristics of the Different High Boiling Fractions from S.B.O.₍₁₎*: An exhaustive study of the characteristics of different high boiling oil fractions prepared from S.B.O.₍₁₎ was made to find out their suitability for scrubbing benzol from coke-oven gas (Tables 2 and 3).

(iii) *Emulsifying Tendency with Water of the above High Boiling Fractions*: The emulsifying tendency with water of different high boiling fractions obtained under (ii), of S.B.O.₍₁₎, in absence as well as presence of coal tar fraction 230-310°C in different proportions was also determined (Table 4).

TABLE 2—CHARACTERISTICS OF DIFFERENT HIGH BOILING OIL FRACTIONS FROM S.B.O. (1)

(A) *Properties of the Oil fraction 230 - 330°C obtained from S.B.O. (1)*

(i) Specific Gravity	..	1.010	at 30°C
(ii) Specific Viscosity	..	1.26°E	at 30°C
(iii) Naphthalene*	..	28% by wt.	
(iv) Tar acids	..	Traces.	
(v) The oil slightly emulsifies with water and slowly separates from the oil water admixture.			

(B) *Properties of the Oil Fraction 270 - 330°C obtained from S.B.O. (1)*

(i) Specific Gravity	..	1.020	at 30°C
(ii) Specific Viscosity	..	1.34°E	at 30°C
(iii) Naphthalene	..	Negligible	
(iv) Tar acids	..	Nil	
(v) The oil slightly emulsifies with water and slowly separates from oil water admixture.			

* The Naphthalene content could be reduced to about 4-5 per cent by collecting the oil fractions 230 - 270°C and 270 - 330°C separately and removing the separated naphthalene.

TABLE 4—EMULSIFICATION WITH WATER OF DIFFERENT BLENDED OILS PREPARED BY MIXING OIL FRACTION 270—330°C OF S.B.O. (1) WITH COAL TAR OIL FRACTION 230—310°C

Sl. No.	Blended Oils Composition		Specific Gravity at 30°C	Observations
	Oil fraction 270—330°C from S.B.O. (1) (by vol.)	Coal Tar Oil Fraction 230—310°C (by vol.)		
1.	2 Parts	1 part	1.030	Emulsifies with water and the oil slowly separates from oil water admixture.
2.	1.5 parts	1 part	1.032	Slightly emulsifies with water and the oil slowly separates from oil water admixture.
3.	1 part	1 part	1.035	Free from emulsification with water and the oil rapidly separates from oil water admixture.
4.	1 part	1.5 part	1.038	Free from emulsification with water and the oil rapidly separates from oil water admixture.

TABLE 3—PARTIAL VAPOUR PRESSURE OF BENZOL OVER SOLUTIONS OF BENZOL IN DIFFERENT HIGH BOILING OIL FRACTIONS FROM S.B.O. (1) AT $31 \pm 1^\circ\text{C}$ AND ATMOSPHERIC PRESSURE

Sl. No.	Benzol Concentration in Benzolized wash oil (g./100 ml.)	Benzol Content of the Vapours (g./m ³) over benzolized		
		Oil Fraction 230 - 330°C from S.B.O. (1)	Oil Fraction 270 - 330°C from S.B.O. (1)	Blended oil* prepared from S.B.O. (1)
1.	2.4	17.6	20.0	19.5
2.	2.0	14.2	16.3	15.5
3.	1.8	11.0	13.0	13.0
4.	1.5	7.8	8.5	8.0

* Blended oil prepared by mixing one part of the oil fraction 270 - 330°C of S.B.O. (1) with one part of coal tar oil fraction 230 - 310°C obtained from distillation of coal tar.

Results and Discussion

A comparative study of distillation range analyses of S.B.O.₍₁₎ as well as S.B.O.₍₂₎ (Table 1) clearly shows that the still bottom oil of the fractionating still for refined light oil products, operating at a distillation temperature of about 160°C, consists largely of high boiling oil fractions and is almost free from lower boiling fractions, whereas the S.B.O.₍₂₎ consists mostly of lower boiling fractions. Since a good wash oil for benzol recovery should have, among other properties, an initial distillation temperature of at least more than 200°C, the S.B.O.₍₁₎ was found to be a potential source of high boiling fractions of coal tar.

The characteristics of different high boiling fractions of S.B.O.₍₁₎ (Tables 2 and 3), examined in the light

of various properties required for a good wash oil, indicate that the fractions 230-330°C and 270-330°C have most of the desirable properties. Both the above fractions have satisfactory benzol absorption capacity, low viscosity and are practically free from tar acids. However, the characteristics of the fraction 270-330°C (Tables 2 and 3) show that it is slightly better than the 230-330°C fraction in almost all respects.

It could be seen (Table 2) that the principal drawback with the above high boiling fractions is that their specific gravity is close to that of water, and because of some emulsifying tendency with water, their separation from the oil-water mixture is slow and incomplete.

In order to improve the quality of the oil fraction 270-330°C of S.B.O.₍₁₎, particularly its specific gravity and emulsifying tendency, blending of this fraction with coal tar fraction 230-310°C obtained from distillation of coal tar, in different proportion was studied. It has been observed (Table 4) that the blended oils, prepared by mixing one part of the fraction 270-330°C of S.B.O.₍₁₎ with one or more parts of the coal tar fraction 230-310°C, have the specific gravity of over

1.035 and therefore do not easily emulsify with water, rather separate rapidly from oil-water mixtures. The blended wash oils, thus produced, are perfectly suitable for light oil scrubbing. The processes for obtaining the required fractions of S.B.O.₍₁₎ and coal tar oil being relatively simple, the respective plants can be installed even in any medium sized by-product coke-oven plant, thereby making it self-sufficient in the supply of wash oil.

Acknowledgement

The authors wish to thank Dr. K. R. Chakravorty, General Manager, Planning and Development Division, for his constant encouragement.

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Estimation of Chloride in an Evaporator Liquor by High-Frequency Titrimetry

By

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Studies have been made on the application of high frequency titrimetry in the estimation of chloride in presence of a large excess of a foreign electrolyte (ammonium sulphate). A method for carrying out this estimation in the evaporator liquor in an ammonium sulphate plant is given.

The main advantage of high frequency titrimetry, now employed in a number of analytical procedures, is that it eliminates direct contact between the chemical system and the electrode as is required in conductometric and potentiometric methods of measurement. It has been successfully applied in the determination of the end-point in argentometric titrations¹⁻⁵ so that chlorides, bromides, iodides, sulphocyanides and

cyanides could readily be estimated. It has also been employed in several other estimations, e.g. of thorium with sodium oxalate⁶, of beryllium with a standard alkali⁷, of sulphate with standard barium nitrate⁸ and of calcium and magnesium with EDTA⁹⁻¹¹.

The present investigation was undertaken to study the applicability of the high frequency method in the estimation of chloride in the evaporator liquor in an

ammonium sulphate plant. This liquor is a saturated solution of ammonium sulphate, containing chloride and other dissolved impurities. The estimation of chloride is particularly necessary since its concentration in the liquor must be kept within a certain limit to prevent corrosion of the evaporator body made of stainless steel. As the evaporator liquor is turbid and coloured, the usual titrimetric methods of estimation of chloride involving the use of indicators are not satisfactory. Hence, a method based upon high frequency titrimetry would be welcome.

Experimental

The apparatus used in the present investigation is the same as that reported in a previous paper¹². The beaker containing the electrolytic solution is placed in parallel with the capacitor circuit. The frequency of 8 megacycles/second is produced by a piezo-electric quartz crystal. The apparatus has a circuit which gives a direct indication of both effective overall conductance and effective overall capacitance changes of the titration cell, and these are read on a calibrated capacitor dial or on a valve voltmeter. The titration cell used is a beaker (250 ml.) made of solidex glass with walls having 0.2 cm. thickness and 8.0 cm. diameter with two electrodes made of copper ribbons, each 1.5 cm. in breadth wound round it at 3.2 cm. apart. The copper bands serving as electrodes could be separated when necessary by loosening screws fitted to them. The titrator is connected to a constant voltage transformer, and the solution is magnetically stirred except when a reading is taken. All the chemicals used were of A.R. grade and the solutions were prepared in conductivity water.

The effective component method is used for all the high frequency estimations. This method is characterized by the fact that every alteration in composition of the solution produces a change in frequency as a result of which the oscillation of the quartz crystal becomes slow. A change in capacity is necessary to restore full vibration in the crystal. These changes in capacity following the change in composition of the solution were noted and plotted against the volume (in ml.) of the reagent added. The graphs showed breaks at the equivalence points (Figs. 1 and 2). In the present study it was preferred to plot the condenser dial readings against the volume of the added electrolyte, because the dial readings were found to vary linearly with capacity.

A measured volume of the solution, to be analysed, was taken in the titration cell (which was sufficient to

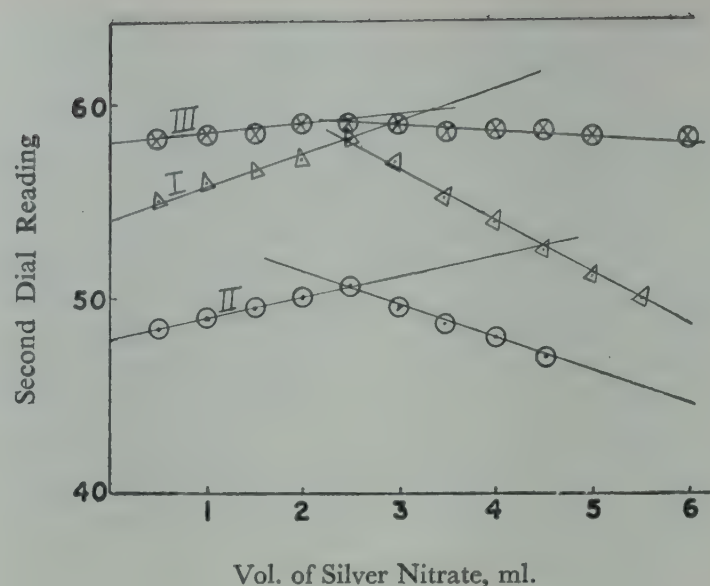


Fig. 1—Effect of a Foreign Electrolyte

- I. 5 ml. of N/100 NaCl made up to 200 ml and titrated with N/50 AgNO₃
- II. 5 ml of N/100 NaCl+0.125 g. of Ammonium Sulphate made upto 200 ml and titrated with N/50 AgNO₃
- III. 5 ml. of N/100 NaCl+0.5 g. of Ammonium Sulphate made up to 200 ml. and titrated with N/50 AgNO₃

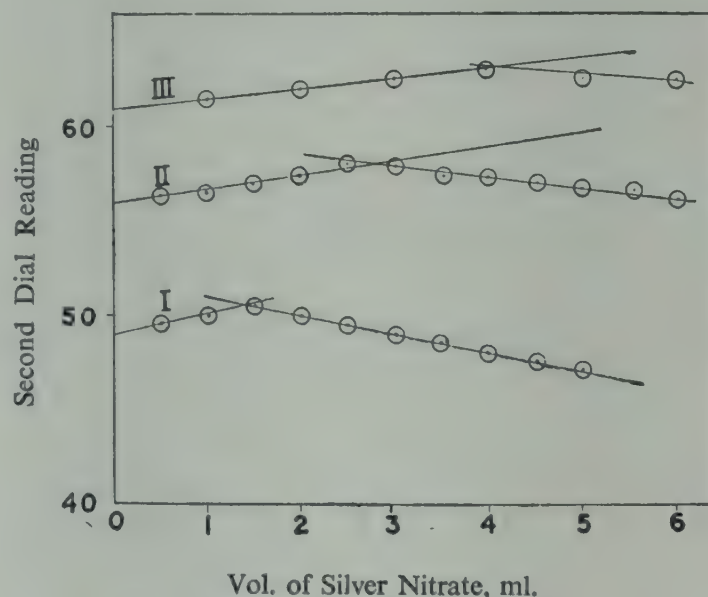


Fig. 2—Effect of Concentration of Liquor

- I. 5 ml. of diluted liquor made upto 200 ml. and titrated with N/50 AgNO₃
- II. 10 ml. of diluted liquor made up to 200 ml. and titrated with N/50 AgNO₃
- III. 15 ml. of diluted liquor made upto 200 ml. and titrated with N/50 AgNO₃

cover both the metal rings), having a capacity of 200 ml. This cell is more suitable for the dilute solution since an increase of the diameter of the cell shifts the inflection point of the response curve to a lower electrolyte concentration^{10,13}. The solution was titrated with a standard silver nitrate solution.

Results and Discussion

It is known that all factors which affect the low frequency conductivity, such as temperature, concentration of electrolyte, ionic mobility, degree of ionization and capacitance will influence the shape of the high frequency titration curve and the additional factors that will be effective in the latter case are operating frequency, dielectric constant of the solvent and the cell constant. In the present study, the operating frequency (8 Mc/s), the cell and the solvent are kept the same in all the experiments and hence the only variables that need to be considered are the concentrations of the various electrolytes present in the solution including those of the foreign (inert) electrolytes.

In order to find out the ranges of concentrations of silver nitrate and sodium chloride over which the high frequency method of estimation of chloride is feasible, different concentrations of sodium chloride were titrated with various concentrations of silver nitrate. It will be seen (Table 1) that sodium chloride having concentrations varying between 1.5×10^{-4} N and 2×10^{-3} N can be titrated against 1×10^{-1} N to 2×10^{-2} N silver nitrate solution—the error varying between 1.1 - 5.0 per cent.

TABLE 1—HIGH FREQUENCY TITRATION OF SODIUM CHLORIDE AGAINST SILVER NITRATE

Normality of Silver Nitrate	Normality of Sodium Chloride*	Volume of Silver Nitrate Required for Complete Precipitation, ml.		Error, %
		Found	Calculated	
1×10^{-1}	1.1×10^{-3}	2.15	2.2	2.2
1×10^{-1}	2.0×10^{-3}	4.20	4.0	5.0
2×10^{-2}	2.52×10^{-4}	2.55	2.5	1.1
2×10^{-2}	4.1×10^{-4}	4.00	4.1	2.5
2×10^{-2}	6.0×10^{-4}	5.80	6.0	3.3
1×10^{-2}	1.50×10^{-4}	2.95	3.0	1.7
1×10^{-2}	2.8×10^{-4}	5.50	5.6	1.8

* Total volume taken = 200 ml.

In applying the high frequency technique to the estimation of chloride in the evaporator liquor in the ammonium sulphate plant, the effect of the major foreign electrolyte, viz. ammonium sulphate, had to be studied. Blaedel and Malmstadt¹⁴ state that the maximum foreign electrolyte concentration that can be tolerated in the high frequency titration is directly

proportional to the operating frequency and that with a frequency of 350 Mc/s a foreign electrolyte concentration up to 1 M can be tolerated. In the present study, a frequency of 8 Mc/s was used, and the foreign electrolyte (ammonium sulphate) concentration that can be tolerated does not exceed 0.02 M (Fig. 1).

From the considerations given above, it was found that the evaporator liquor from the ammonium sulphate plant at Sindri should be diluted 30-50 times for the estimation of chloride in it by the high frequency method. 10 ml. of the evaporator liquor was diluted with distilled water to 100 ml. and kept as stock solution. From this diluted solution, 5, 10, 15 ml. etc., are diluted to 200 ml. and titrated with $\frac{N}{50}$ silver nitrate in the high frequency titrator. From Fig. 2, it will be observed that as the amount of stock solution taken increases, the sensitivity of the high frequency titration decreases due to the higher concentration of foreign electrolyte (ammonium sulphate). The results (Table 2) show that the error increases as the volume

TABLE 2—ESTIMATION OF CHLORIDE IN THE EVAPORATOR LIQUOR

Evaporator Liquor Sample No.	g. NaCl/100 ml. by Volhards Method ¹⁵	g. NaCl/100 ml. by High Frequency Titration	Error, %
1	0.314	0.317 ^a	0.90
		0.310 ^b	1.20
		0.324 ^c	3.10
2	0.188	0.186 ^a	1.06
		0.185 ^b	1.57
		0.195 ^c	3.7
3	0.228	0.230 ^a	0.86
		0.225 ^b	1.31
		0.224 ^c	1.74

a - 5 ml of diluted liquor taken for titration.

b - 10 ml of diluted liquor taken for titration.

c - 15 ml of diluted liquor taken for titration.

of stock solution taken is increased from 5 to 15 ml. With 5 ml. the error is one per cent or less, with 10 ml. of the solution the error is within 2 per cent, while with 15 ml. of the solution the error is within 4 per cent.

The high frequency titration technique thus provides a convenient method for the estimation of chloride in the evaporator liquor in the ammonium sulphate plant.

The authors wish to thank Dr. K. R. Chakravorty, General Manager, for his interest in this work.

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Notes & News

Science and Self-Reliance Exhibition

The Planning and Development Division of FCI Ltd. participated in the Science and Self-Reliance Exhibition held during May 9 to 13 on the grounds of Parliament House, New Delhi, organized under the auspices of the Indian Parliamentary and Scientific Committee.

The exhibits—in the form of photographs, flowsheets, charts, samples of products, etc—were designed to give a glimpse into the wide range of activities and achievements of this Division. The activities cover the various integrated functions, comprising research and process development, project planning and design, various branches of engineering of plants and equipment, technical procurement, supervision of plant erection and commissioning, highlighting investment costs and savings in foreign exchange, with the aim of achieving complete technological self-sufficiency in the nearest future.

The results achieved in the field of process and product development with indigenous resources and know-how developed in this Division were also exhibited along with products, such as the low and medium pressure CO-conversion catalysts, reformation catalysts, desulphurization oxide and hydrodesulphurization catalysts so vitally required in fertilizer production as well as for ammonium bicarbonate, ion-exchange resins, polyphosphate and sodium nitrite, improved process for ammonium sulphate from gypsum and phosphoric acid and slagging gas generator pilot plants. Some of these products, like the desulphurization mass and CO-conversion catalyst, have now totally substituted imported materials and are in regular use in the FCI's commercial plants.

The results of extensive agronomical experiments carried out at the division's field experimental station, established with the main idea of evaluation, utilization and demonstration of fertilizers produced by FCI, and for making recommendations for the pattern of fertilizers to be used consistent with the actual needs of the



Science and Self-Reliance Exhibition, New Delhi

country and its resources of raw materials, were also exhibited. A significant exhibit depicted that citrate-soluble carbonitric nitrophosphate is quite suitable and acceptable for various crops including paddy in India.

Total Energy Concept for Lummus Ammonia Plant

A 600 ton/day anhydrous ammonia plant is designed by the Apple River Chemical Company to utilize Lummus steam-reforming process based on natural gas-total energy concept. The plant uses natural gas as both raw material and process fuel. The total energy concept is applied by also making natural gas the only source of energy for electrical power, steam and for the operation of the gas engine-driven compressors. After steam-reforming and carbon monoxide shift conversion, the carbon oxides are removed by scrubbing the gas with a hot potassium carbonate

solution containing an activating agent. This efficiently removes the carbon dioxide down to a small concentration. The carbonate, containing the absorbed carbon dioxide, is regenerated for continued recirculation. The carbon dioxide and monoxide, remaining in the synthesis gas, are finally eliminated by methanation.

The reaction process takes place in the presence of a catalyst, with the exit gas from the carbon dioxide absorber being preheated to about 550°F. Ammonia is produced by direct combination of nitrogen and hydrogen under pressure of 4,600 psi in a converter containing promoted iron oxide type of catalyst. The gases enter the converter and flow down through the annulus between the internals and the shell. The flow reverses at the bottom of the converter and the gases enter the tubes of the feed-effluent exchanger. At the top of the converter the flow is again reversed and the gases pass



Smt. Indira Gandhi, Prime Minister, at the P & D Division's Stall
(Science & Self-Reliance Exhibition)

downward through the catalyst bed. Unreacted and noncondensed gas forms the recirculation system, which is recompressed and mixed with synthesis gas, and the concentration of inerts in the synthesis loop is controlled by a continuous gas purge.

Ammonia is reduced to about 300 psi to remove most of the gases, and the liquid ammonia chilled to -30°F is withdrawn to storage.

The gases from the pressure let-down unit and the purge gases from the loop pass through a low temperature refrigeration system for maximum recovery of ammonia and are used as fuel for the primary reformer.

[Chemical Age, 95 (1966), 2436, 485]

Melamine From Urea

Most of the melamine at present is obtained using the conventional dicyandiamide route which, because of various processing steps involved, has high production cost. In 1961 the American Cyanamid introduced a new process by heating urea at $750\text{--}930^{\circ}\text{F}$ above 1420 psi. Ammo-

nia and carbon dioxide are also produced as by-products



The high pressure has, however, the following disadvantages—costly equipment is required because of the corrosive nature of the reaction and the high melting point of melamine— 669°F ; for precise control of the process, melamine must be recrystallized.

Nissan Chemical Industry of Japan has developed a process by pyrolysis of urea under pressure from associated waste gases, mainly ammonia and carbon dioxide. The molten melamine and the associated waste gases emerging from the synthesis reactor are brought into contact with a quantity of a cool gas sufficient to provide the resultant mixture a temperature of $60\text{--}100^{\circ}\text{F}$, whereby the molten melamine solidifies and separates from the gases. Rapid cooling of the molten melamine to the solid state is required to prevent deammoniation.

Recently Österreichische Stickstoffwerke AG., of Linz, Austria have announced a new two-stage route to melamine from urea

obtained at atmospheric pressure, and the product which is 99.9 per cent pure does not need to be recrystallized. Fertilizer-grade urea is decomposed at 662°F , using an externally-heated reactor, which contains a fluidized bed of abrasion resistant, non-metallic material. Urea is blown in from below with ammonia as the carrier gas. A mixture of cyanic acid and ammonia is obtained: $\text{CO}(\text{NH}_2)_2 \rightarrow \text{HNCO} + \text{NH}_3$. The gaseous mixture is then passed over a catalyst, whereby the cyanic acid is converted into melamine: $6\text{HNCO} \rightarrow \text{C}_3\text{N}_6(\text{NH}_2)_3 + 3\text{CO}_2$. The temperature of the catalyst is such as to cause immediate sublimation of melamine. Rapid quenching with water then removes it from the reaction gases and the resulting melamine-water slurry is separated by centrifuging. The melamine obtained is a commercially usable product immediately after drying operations.

OSW stresses that for product purity reaction, conditions at the catalyst stage are important. The temperature is to be controlled from $842\text{--}878^{\circ}\text{F}$, otherwise by-products may be formed and the melamine has to be recrystallized. The gas feed temperature ranges between $590\text{--}626^{\circ}\text{F}$.

The reaction is carried out under adiabatic conditions, and in order to prevent secondary reactions the melamine in the gas phase is quenched and brought into aqueous suspension as quickly as possible. In the final processing stages, cleanliness is maintained to prevent contamination. After centrifuging, the separated melamine is washed with water, dried and ground to 0.005-0.5 mm. size.

All the plant equipment coming into contact with the final product is of stainless steel, aluminium or plastic. Ammonia and carbon dioxide are obtained as by-products. To eliminate carbon dioxide the gases leaving the melamine separator are scrubbed with aqueous ammonia and the ammonia gases are cycled.

Processes for melamine based on urea are more economic. Some 3.35 tons of urea are required to produce 1 ton of melamine. Just under 1 ton of ammonia and more than 1 ton carbon dioxide are produced as by-products.

[Nitrogen, No. 40, March/April 1966, 40]

New Outlook on CO-Conversion

With the introduction of new low temperature CO-conversion catalysts, a dramatic change has come in the catalytic process of the water-gas shift reaction and consequently in the production of synthesis gas. At present the plants with 22 per cent of the world's nitrogen supply are using these catalysts, and it is expected that by the end of 1966 over 47 per cent of the world's projected ammonia supply will be produced using these catalysts.

The conventional promoted iron oxide for the water gas shift reaction ($\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$) is effective over a range of 650-950°F yielding 80-85 per cent conversion of the carbon monoxide. Adding a second bed of conventional catalyst after cooling or quenching, the conversion increases to about 90 per cent.

A two-stage system, viz. scrubbing out of carbon dioxide between two stages, of carbon monoxide conversion with the conventional catalyst permitted the degree of conversion to increase to 95-96 per cent. In contrast to this, the low temp. shift catalyst permits 96-98 per cent conversion of carbon monoxide in a single stage, and can reduce the operating costs and the physical size of an ammonia plant by about 15 per cent.

But low temperature catalysts are about three times costlier than the conventional

catalyst on a unit volume basis, and their ultimate useful life is not yet known beyond 18 months, whereas the latter has a life of about 5 years.

[Nitrogen, No. 40, March/April 1966, 28]

Ammonia Increases Boiler Efficiency

A limit to the efficiency of industrial boilers, which depends on more heat extracted from the combustion gases and therefore less exit temperature, is set by the tendency of sulphur trioxide and water vapour in the combustion gas to condense out as a sulphuric acid dew if the temperature falls too low. This causes severe corrosion of the boiler surfaces.

By operating the boiler with little excess oxygen (under 1 per cent), corrosion is minimized, but this requires extremely good instrumentation and control. Another approach is to neutralize the acid gas by injection of ammonia. While this technique has been tried before to reduce sulphur trioxide concentrations, no attempt has hitherto been made to exploit the low exit temperature which it makes possible.

B. Lees and L. K. Rendle of British Petroleum Ltd have made an experiment in which an industrial boiler of the 'economic' type was modified to investigate this possibility. The boiler normally operated at a steaming capacity of 5000 lb/hour and burned a standard fuel oil. An economizer (feed-water heater) of finned cast-iron tubing was fitted in the path of flue gases which normally escaped at 230°C so that their final exit temperature fell to 90°C. In order to examine the extent of corrosion of the economizer, a washing system was fitted so that the economizer could be sprayed with water at definite intervals, and the collected wash-liquid analysed for dissolved iron. A separate iron test-plate was held in the gas stream and similarly washed. The temperature of the test plate was varied to study the influence of this factor.

It was found that with no ammonia injection, loss of metal rose rapidly as the temperature fell, reaching a maximum at about 90°C. Injection of ammonia into the gas stream on the inlet side of the economizer reduced this level. At the optimum injection rate, only 12.1 lb of iron were lost in 1000 hours—a very low figure. This was achieved by an ammonia consumption of 0.0006 lb to each lb of fuel burned to neutralize all the sulphur trioxide in the combustion gas. The increased efficiency of

the boiler led to a fuel-saving of 8.5 per cent.

[New Scientist, 29 (1966), 553]

Formamide as a Component of Liquid Fertilizers

In liquid fertilizers the problem of low nutrient content adversely affects the cost of storing, handling and transportation.

TVA is studying the suitability of formamide—the acid amide of formic acid, containing 31 per cent N—in the preparation of higher nutrient content liquid mixed fertilizers. Formamide is a liquid with a low vapour pressure at ordinary temperatures and is miscible with ammonia and water. It is a solvent for many fertilizer salts. Non-pressure solutions, containing 34.1 to 35.5 per cent nitrogen and salting out at 5 and 32°F respectively, were prepared from urea, ammonium nitrate and formamide. It is found that formamide-urea-water solutions containing 31.5 and 33.6 per cent nitrogen salted out at 0 and 32°F. Salting out temperatures of urea-ammonium nitrate solution was lowered from 32 to 20°F by addition of formamide; covering of nitrogen content was only from 32 to 31.8 per cent. Formamide and solution containing formamide were effective in greenhouse tests. In liquid formulations, containing 11-37-0 base solution, potassium chloride, and water, additions of supplemental nitrogen as formamide generally gave lower salting-out temperatures than comparable additions such as urea and ammonium nitrate. But the disadvantage of formamide is that of its high cost. Possibilities of new methods of synthesis of formamide at lower costs are being explored.

[Nitrogen No. 40, March/April 1966, 44]

Anhydrous Ammonia Symposium

Agricultural Ammonia Institute in co-operation with the American Society of Agronomy and Soil Science Society of America organised a symposium in September 1965 at St. Louis (U.S.A.), where from manufacturing of ammonia to the nitrogen requirements of plants and other agricultural uses of ammonia were discussed. Petroleum has now become the main source of hydrogen recovered in an efficient way, thus reducing the cost of ammonia manufacture.

It is now possible to store and transport ammonia by barge at low temperatures and

utilize pressure storage vessels only at the point of retail sale. The logistics and economics of transporting, storing, and applying anhydrous ammonia to permit year-round production for distribution and application in only a very few weeks of the year still are one of the most pressing problems facing the industry. From the tests carried out at varied locations, it was found that response to application of nitrogen as ammonia compares favourably with equal amounts of nitrogen from other carriers. Relative response may vary slightly from location to location and under different circumstances. Losses in application were very small—almost negligible—when the ammonia was applied in suitable soils.

Economics of anhydrous ammonia properly applied equals or exceeds that of nitrogen from other carriers. However, economic data based on the actual use of anhydrous ammonia is rather limited and more studies are needed.

Use of nitrogen in agriculture will exceed 10 million tons of actual nitrogen by 1980. However, this rate of use could develop much more rapidly, given the right set of conditions.

Anhydrous ammonia reacts directly with organic matter in the soil and is held on the exchange complex of the organic matter, as reported by F.E. Broadbent and F. J. Stevenson of the universities of California and Illinois respectively. They stated that the quantity of organic matter in the soil is one of the most important factors in the ammonia-holding capacity of soils.

Biological transformations of ammonia start in soils almost immediately upon application of anhydrous ammonia. It is the favoured source of nitrogen for use by bacteria in the decomposition of crop residues. Nitrification is one of the most important transformations. As the soil becomes more acid, the rate of nitrification slows. The most favourable conditions include temperatures of 47° to 90°F, a pH approaching 6.5, and adequate moisture and air. As any one of these rates decreases or becomes less favourable, the rate of nitrification will decrease. Nitrification comes to an almost complete halt when soils are frozen. At temperatures only slightly above freezing, the rate of nitrification, when all other conditions are favourable, will approach five to ten per cent of the rate at 70°F.

The kind and amount of clay and the amount of organic matter are the two most important factors in determining the

ammonia-retention capacity of soils. Even sandy soils that have almost a minimum amount of organic matter will hold the equivalent of 1,000 pounds of nitrogen as ammonia in an acre-foot of soil.

The mechanisms by which ammonia is absorbed by minerals ranges from weak physical forces to strong chemical bonds. Formation of the ammonium ion results, when hydrogen ions on the exchange complex react with ammonia.

Ammonia and water compete for co-ordination positions on the metal ions and each can displace the other. After ammonium ion is formed, it may be rendered non-exchangeable if vermiculitic minerals are present in the soil when they are in this non-exchangeable or "fixed" condition, they are not available for plant or microbial utilization.

Great interest in additives to ammonia was reported by W.C. Scott Jr. of TVA and S.L. Tisdale of the Sulphur Institute, but research data are available only on sulphur. Sulphur in various forms has been successfully added to anhydrous ammonia in several ways and has given profitable agricultural response in those years where the sulphur need has been demonstrated.

Anhydrous ammonia's use as a defoliant on cotton, especially in California and other irrigated regions on the west has been discussed. Ammonia will kill the cotton leaves and the stems will develop normal abscission layers and will drop off, but the plant will not be killed. If conditions are not favourable for picking but are favourable for regrowth, regrowth can occur. Significant amounts of nitrogen are retained in the leaves and stems of the cotton plant and are returned to the soil for use by the succeeding crop.

[NPKS Abstracts, 69 (1966), Jan. 7]

Phosphate Deposits of India

In association with the geological organizations of India, Mr. Richard P. Sheldon of the U.S. Geological Survey conducted a survey on the India's phosphorite potential deposits. The study concerned mainly on the general stratigraphy and structure and potential of the phosphorite deposits of Mussoorie (U.P.) and Birmania ore of West Rajasthan.

(a) *Jurassic Phosphorites of the Himalayan Foothills Around Mussoorie*: First discovery in 1884 reports findings of a 6 inch bed of phosphate nodules occurring over a limestone and under a black chert.

Subsequent investigations revealed 8 feet of phosphorite spread through 20 stratigraphic feet, and 6 of this 8 feet spread over 10 stratigraphic feet. Tests of these rocks revealed that this phosphorite is low to medium grade phosphate with 10 to 20 per cent P_2O_5 .

The chert black shale phosphorite formation occurs at the base of the Tal series and overlies the Krol series. Because of this rock association, it is stated that this phosphorite is not of medium to deep water marine origin and was originally very widespread. These phosphorite beds are found usually dipping at high angles, as the Krol and Tal series are folded and faulted. The Krol and Tal series are found between Simla and Nainital. Probably the chert black shale phosphorite formation will be found over this area. The Jurassic rocks of a different series, but containing black shales, which are found deeper in the Himalayas, may also contain phosphorite. The potential of the Jurassic phosphorite horizon of containing minable phosphate deposits seems high. The stratigraphic section has not been examined completely.

There is the possibility of finding minable deposits with reserves of the order of magnitude of hundreds of millions of tons near the upper contact of the black shale. The above are crude extrapolations based on geological deductions. So there is also a chance that no major minable deposits will be found.

(b) *Paleozoic Phosphorite of Rajasthan*: Phosphorite of Paleozoic age was discovered near Birsinga in Rajasthan. It was confirmed by the Oil and Natural Gas Commission of the existence of a small outcrop of Paleozoic limestone, black shale and chert called Birmania Formation, south-west of Jaisalmer. Exploration of the area revealed many beds of phosphorite, one about 5 feet thick and abundant phosphorite float in the Birmania Formation. Several strike valleys are developed in the formation. The parts of the section most likely to contain the best phosphorite are covered but have not been examined.

The grade of the phosphorite seen is low to medium with chert being the main diluent. In general, the stratigraphic section consists of interbedded red shale, limestone and sandy limestone at the base overlain by cherty limestone, which in turn is overlaid by chert, phosphorite and probably dark shale. The present known outcrop of the Birmania Formation is small, only several miles in length.

North and east of Jodhpur, flat lying cherty limestone, probably of the same age of Birmania, crops out extensively and is overlaid conformably by bouldery sandstone of Permian age. This sequence is overlapped by Jurassic rocks. These cherty limestones and associated beds may contain phosphorite. Thus, the phosphorite beds

may be much more extensive than the small outcrop northwest of Birsinga.

The potential of the Birmania Formation for containing minable deposits of phosphate rock seems high, and it is likely that higher grade phosphorite occurs in the formation than was seen in outcrop.

Mr. Sheldon recommends for further

exploration in the following lines: (1) reconnaissance geology of the large areas; (2) detailed mapping of areas containing phosphate rock; and (3) stratigraphic studies of the phosphorite-bearing formations including trenching, drilling and sampling.

[FAI Inf. Serv., 7 (1966), 11, 6]

News in Brief

Pool Prices of Imported Fertilizers

Government of India have fixed the pool prices of the following imported fertilizers with effect from April 28, 1966.

(1) Ammonium Chloride (with 25 per cent nitrogen): At Rs. 400.00 /metric ton, gross, f.o.r. ports/despatching station, freight paid by the Central Fertilizer Pool up to rail head destination by the shortest and cheapest route.

(2) Diammonium Phosphate (18-46-0): At Rs. 750.00/metric ton, gross, f.o.r. ports/despatching stations freight paid by the Central Fertilizer Pool.

High-Analysis Fertilizers in the U.S.S.R.

For the first time, higher-concentration fertilizers have begun to exert a significant influence on the fertilizer industry of the Soviet Union. Prior to 1964, the industry had been dominated by single-nutrient low analysis fertilizers. In 1964, production of phosphate fertilizers, including ground phosphorite, rose by one-third and potash production increased by 500,000 tonnes K_2O . By 1970 the Soviet Union plans to raise the average nutrient concentration of nitrogenous fertilizer from 31.1 per cent in 1963 to between 34 and 35.5 per cent principally through the large-scale production of ammonium nitrate (34.5%N) and urea (46%N). Details are given of the basic types of fertilizers, new plant capacity, reported projects, raw materials and regional distribution of production.

The Soviet Union's nitrogen fertilizer industry still has problems to solve, and there is concentrated research devoted to its products. Efforts are also being made to improve the distribution and application methods.

[NPKS Abstracts, 69 (1966), 17]

World's Largest Plant for Converting Garbage into Compost

The largest plant in the world converting

town garbage into compost for soil fertilization is the V.A.M. at Wijster, the Netherlands. The company was established in 1931, and the plant has since produced two million tons of compost by a modern biological fermentation process. By means of high temperature, all disease germs and seeds of weeds are destroyed. 80 per cent of the products of the V.A.M. are of finer quality to be used in horticulture and recreational fields, parks etc., and the rest used for arable farming.

[The Netherlands Monthly, April, 1966, Netherlands Embassy, New Delhi]

Compound Fertilizers in Japan

Nissan Chemical Industries of Japan is to market a high analysis compound fertilizer—Huminphoska—an impregnated dibasic ammonium phosphate and activated humic acid obtained from Hokkaido Colliery and Steamship Co. At least 3000 tonnes will be used as a fertilizer for tobacco in the Kanto district.

Toyo Koatsu Co. has succeeded in producing a new fertilizer viz. 2-amino 4-chloro 6-methyl puridine, which when mixed with nitrogenous material—ammonium sulphate or urea—checks loss of ammonia. In field tests the new fertilizer, it is claimed, increased crop yields by 3-5 per cent and was especially helpful in rice cultivation.

[Nitrogen, No. 40, March/April 1966, 48]

Safety Award to Nangal

An award and a silver cup, under the National Safety Award Scheme for achieving 'greatest percentage reduction in frequency rate' for the year 1965, were presented to the Nangal Fertilizer Factory of the FCI Ltd., on March 29, 1966 by Sri Jagjivan Ram, Union Minister for Labour, Employment and Rehabilitation.

The good safety record of Nangal factory for 1965 has also been similarly recognized

by the National Safety Council of USA and the Punjab Government. A communication from NSC (USA) announcing the award for 'outstanding safety record' states that such an award 'is not easy to earn—not even 10 per cent of the plants enrolled for council membership win awards in any year.'

Nangal factory had also received in November 1964 the Presidential Award for its good all round performance.

[FCI News, 4 (1966), 4, 4]

A Promising Potash-Magnesia Fertilizer

Schoenite, a double sulphate of potassium and magnesium, is a cheap source of fertilizer potassium as compared to potassium sulphate. Schoenite can replace potassium sulphate in fertilizer mixtures provided the molar ratio of Ca:Mg and K:Mg in fertilizer mixture is more than two. General fertilizer mixtures of different compositions are formulated in which schoenite is the source of between 70 and 100 per cent of the total K_2O in the mixture. Proposals for manufacture of schoenite from sea bittern, according to the process evolved at the Central Salt & Marine Chem. Research Institute at Bhavnagar, are under consideration. If schoenite is utilized for formulation of fertilizer mixtures, there will be a considerable saving in our valuable foreign exchange.

[Salt Research & Industry, 2 (1965), 4, 143]

New Synthesis Gas Process

A process for ammonia synthesis gas, developed by the Badische Anilin and Soda Fabrik, has now been put on a commercial scale at their Ludwigshafen Works. The method is an adaptation of an older BASF process based on methane feed-stock. Employing a naphtha feed, it is claimed to be the first synthesis gas process which neither produces carbon black nor

requires pretreatment (e.g. desulphurization) of the naphtha. It operates at atmospheric pressure, gives high yields, consumes less oxygen and needs less catalyst replacement than do the high pressure operations.

Essentially a combination of partial oxidation and steam-reforming, the process calls for oxidizing some of the naphtha feedstocks with oxygen or oxygen-rich air. This supplies the heat needed for subsequent endothermic reaction of the remain-

ing hydrocarbons with steam. As in the methane process, a platinum catalyst is employed for the partial oxidation stage but the furnace has been redesigned so that there is practically no time interval between the mixing of the feed gases and the partial oxidation, thus leading to the avoidance of flame and carbon black production. For the thermal cracking stage, BASF has developed new homogeneous nickel catalysts said to exhibit only a minor poisoning effect at high sulphur exposure. Feeds with

a sulphur content of 300 ppm. have been used with success.

[Chem. Tr. J. & Chem. Engr., (1966),
Jan. 27, 85]

Membership

Sri S. N. Roye, Technologist (Technical Publications Officer), P. & D. Division, has been admitted as an Ordinary Member of the Indian Association of Special Libraries & Information Centres (IASLIC), Calcutta.

CORRIGENDUM

Ref. Table 6—*Manufacture of Sulphuric and Nitric Acids in India, Technology, Vol. 3, No. 1, 1966, p. 57.*

The installed capacity of Nitric Acid for the Years 1961, 1962, and 1963 may be read as 596 m.t., 596 m.t. and 1179 m.t. respectively.

[Private Communication from the Asst. Director, Deptt. of Statistics, Central Statistical Organization, Calcutta-1]

STATISTICS

TABLE 1—PRODUCTION OF CAN & HEAVY WATER AND CONSUMPTION OF PROCESS MATERIALS, CHEMICALS, ETC. AT FCI'S NANGAL WORKS

Year	1961-62	1962-63	1963-64	1964-65	1965-66
I Products					
(a) Calcium Ammonium Nitrate, metric tons	200780	284322	374000	372241	337952
(b) Heavy Water, kg.	—	5249.51	11733.40	11172.2	8912.1
II Consumption of Raw Materials, Chemicals, Etc.					
(a) Limestone, metric tons	81315.90	116571.42	154937.60	153736.16	139626.679
(b) Soapstone, metric tons	1106.706	687.08	897.493	606.175	547.5
(c) Fuel Oil, metric tons	1357.430	1447.559	1629.655	1383.857	1163.684
(d) KOH, metric tons	134.24	192.118	343.723	712.921	610.095
(e) Chlorine, kg.	5033.127	6304.0	11141.0	15514.0	13415.0
(f) Caustic Soda, kg.	58276.0	46769.0	48319	54400	40220
(g) Aluminium Sulphate, kg.	2401.0	4440.0	1270	990	620
(h) Lime Hydrate, kg.	9297	52437.0	49381	43818	34958
(i) Sulphuric Acid, kg.	94659	71236	74198	88802	57590
(j) Platinum Catalyst, g.	15136.4	19368	25451	24681	19356.40
(k) Ammonia Catalyst, g.	20324	17249.5	15168.5	11607.5	9178.6

[Communication from FCI Ltd. Nangal, Punjab]

TABLE 2—PROBABLE PRODUCTION OF PHOSPHATES (P₂O₅) DURING THE FOURTH PLAN

(metric tonnes)

S. No.	Factories	Capacity (P ₂ O ₅)	Date of first production/ Production during 1965-66	Anticipated Production (P ₂ O ₅)				
				1966-67	1967-68	1968-69	1969-70	1970-71
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I Existing:								
(a) Established prior to 1965-66								
	(i) Superphosphate factories	.. 169,770	Existed					
	(ii) FACT: (first two stages)	.. 6,700	prior to					
	(iii) E.I.D.—Parry: Ennore	.. 11,000	1965-66					
		187,470	106,760	131,229*	131,229*	131,229*	131,229*	131,229*
(b) Established during 1965-66								
	(i) FCI: Trombay ..	.. 45,000	Nov. 1965 9,000	31,500	31,500	31,500	31,500	31,500
	(ii) FACT: (Third stage) ..	.. 20,730	Dec. 1965 2,940	14,510	14,510	14,510	14,510	14,510
	(iii) Coimbatore Pioneer: Coimbatore	6,500	Nov. 1965 1,300	4,550	4,550	4,550	4,550	4,550
		72,230	13,240	50,560	50,560	50,560	50,560	50,560
	Sub-total ..	.. 259,700	120,000	181,789*	181,789*	181,789*	181,789*	181,789*
II Under construction								
	(i) Coromandel: Vizag ..	.. 73,000	Dec. 1966	10,335	51,100	51,100	51,100	51,100
	(ii) Gujarat State : Baroda ..	.. 56,900	Aug. 1967	—	21,330	39,830	39,830	39,830
	(iii) FACT—Fourth stage Expansion ..	.. 10,000	Jul. 1968	—	—	4,335	7,000	7,000
	(iv) Superphosphate factories—							
	(a) Alembic Chemicals (Exp.) ..	.. 1,610	Jun. 1968	—	—	790	1,130	1,130
	(b) Bharat Fertilisers: Bombay ..	.. 3,600	Jun. 1968	—	—	1,770	2,520	2,520
	(c) West India Chemicals (Exp.) ..	.. 4,990	Jun. 1967	—	2,480	3,490	3,490	3,490
	(d) J. K. Cotton, Kanpur ..	.. 6,520	Aug. 1967	—	2,450	4,565	4,565	4,565
	(v) Dicalcium phosphate: Atul Products, Bulsar ..	.. 2,800	Aug. 1967	—	1,040	1,960	1,960	1,960
	(vi) Triple superphosphate: DMCC, Bombay ..	.. 11,880	Dec. 1966	1,680	8,320	8,320	8,320	8,320
	Sub-total ..	.. 171,300		12,015	86,720	116,160	119,915	119,915
III Licensed and expected to go on stream in Fourth Plan:								
	(i) Madras Fertilisers: Madras ..	.. 110,000	Jan. 1969	—	—	9,170	77,000	77,000
	Sub-total ..	.. 110,000		—	—	9,170	77,000	77,000
	Total: (I), (II) & (III)	541,000		193,804	268,509	307,119	378,704	378,704

Table 2 (Contd)

(metric tonnes)

S. No.	Factories	Capacity (P ₂ O ₅)	Date of first production/ Production during 1965-66	Anticipated Production (P ₂ O ₅)					
				1966-67	1967-68	1968-69	1969-70	1970-71	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
IV Under consideration:									
	(i) Metal Corporation of India: Udaipur (Superphosphate)	..	12,190	April 1969	—	—	—	1,665	8,535
	Sub-total	12,190		—	—	—	1,665	8,535
	Total	553,190		193,804	268,509	307,119	380,369	387,239

*Estimated at 70 per cent of installed capacity. Due to shortage of raw materials the estimated production during 1965-66 is 120,000, tonnes.

- Notes: 1. It is assumed that during the first three months (trial run), production of new units will be 1/3rd of monthly installed capacity, and thereafter at 70 per cent.
2. Pattern of end products in the case of Barauni, Haldia, Mangalore and Gujarat Expansion is not available. Their contribution to P₂O₅ has, therefore, not been taken into consideration here.
3. FCI: Durgapur, Cochin Fertilisers: Cochin and Birla Gwalior: Goa will be producing only urea during their first phase of production programme which is likely to be completed by 1968-69. Their contribution to P₂O₅ has, therefore, not been considered here.

[Fertilizer News, 11 (1966), 6, 27]

TABLE 3—PRELIMINARY ESTIMATES OF OUTPUT AND CONSUMPTION OF COMMERCIAL FERTILIZERS IN THE FERTILIZER YEAR 1964-65

('000 metric tonnes)

Continent	Nitrogenous (N)		Phosphate (P ₂ O ₅)		Potash (K ₂ O)	
	Production	Consumption	Production	Consumption	Production	Consumption
Europe	6,979	5,852	5,674	5,573	6,434	5,500
U.S.S.R.	2,099	*2,040	1,407	*1,360	1,800	*1,400
North & Central America	4,884	4,861	4,086	3,634	3,500	2,900
South America	*332	*307	*163	*328	*35	*212
Asia	1,947	2,091	834	1,082	200	850
Africa	*200	*522	*388	*373	—	*167
Oceania	29	63	1,128	1,136	—	155
World Total	16,470	15,740	13,680	13,490	11,970	11,180

*Unofficial estimates.

According to preliminary estimates released by the FAO Fertilizer Industry Advisory panel, world fertilizer production (excluding mainland China) in 1964-65 was more than 10 per cent over the previous year's figure. World consumption of all fertilizers (excluding mainland China) totalled nearly 40.5 m. tons, an increase of 11.5 per cent over 1963-64. The largest estimated increase in output was shown by Europe (1.5 million tons). Asia showed a sharp increase of about 4 lakh tons.

The heaviest rate of application was still found in Europe, with a consumption of some 110 kg of all fertilizers per hectare of arable land. This compared with 45 kg. in North and Central America, 39 kg. in Oceania, 22 kg. in the U.S.S.R., 11 kg. in S. America and Asia and only 4 kg. in Africa.

[Agricultural Chemicals, 21 (1966), 3, 102]

TABLE 4—COST OF PRODUCTION OF HYDROGEN BY DIFFERENT PROCESSES UNDER CONDITIONS IN USA

		<i>Natural Gas Reforming</i>	<i>Naphtha Reforming</i>	<i>Partial Oxidation fuel oil</i>	<i>Coal Gasification</i>	<i>Water-gas Process</i>	<i>Steam-Iron Process</i>	<i>Electro- lysis of water</i>
Plant Capacity 10 ⁶ SCF/d10 ³ Nm ³ /d	..	25 707	25 707	25 707	25 707	25 707	25 707	4 113.2
Hydrogen purity, % pressure, atm.	..	97 8.5	97 8.5	96 30	96.9 7	99.8 20	99.1 7	99.8 29
Capital cost, mill Rs. Rs/10 ³ Nm ³ /d	..	11.65 16,450	15.45 21,800	22.25 31,400	53.2 75,000	69.75 98,600	50.3 71,000	1,905 17,600
Prices: Feedstock, Rs/t Fuel, Rs/10 ⁶ Kcal		90.6 7.54	80.4 7.54	43.65 4.43	23.75 3.38	47.5 6.34	— 3.38	— 44.2
Power, Rs/Kwh	..	0.0475	0.0475	0.038	0.0356	0.038	0.0356	0.038
Steam, Rs/t	..	—	—	8.36	—	6.0	—	—
Boiler water, Rs/1000 gal	..	4.75	4.75	—	—	—	—	—
Production Cost, Rs/10 ³ Nm ³	..	42.2	50.8	71.8	72	194	72	200-34*=166
Partition of cost								
For Gasification, Rs (a)	..	29.35	33.31	26.77	16.73	154.12	—	—
„ CO-Shifting, „ (b)	..	7.28	10.50	31.20	37.60	27.60	—	—
„ CO ₂ Removal „ (c)	..	4.40	5.40	9.74	12.65	8.65	—	—
Total purification, (b+c+10% excess)	..	12.85	17.49	45.03	55.27	39.88		*Credit for O ₂

[Chem. Age of India, 17 (1966), 3, 174]

TABLE 5—NITROGEN FERTILIZER PRODUCTION IN INDIA
(1966)*

('000 tonnes N/ year)

<i>Status</i>	<i>Public Sector</i>	<i>Private Sector</i>	<i>Total Nitrogen</i>	<i>Total Hydrogen Require- ment**</i>
In Production	548.30	18.25	566.55	142.8
Under Erection	221.00	80.00	301.00	76.0
Projects Approved	432.00	628.00	1060.00	266.8
(expansion and new)	387.00	Nil	387.00	97.7
Total	1588.30	726.25	2314.55	583.3

*Excludes 20,000 N as by-product ammonia from coke oven plants.

**Accounts for efficiency of utilization.

[Chem. Age of India, 17 (1966), 3,141]

TABLE 6—SOURCES OF HYDROGEN FOR SYNTHETIC
FERTILIZER MANUFACTURE IN INDIA UP TO 1971

('000 tonnes hydrogen/year)

<i>Source</i>	<i>In Production</i>	<i>Under Erection</i>	<i>Approved and Proposed Projects</i>	<i>Total</i>
Electrolysis	21.7	—	—	21.7
Coke oven gas	40.3	—	—	40.3
Coal/coke/lignite	39.6	—	16.1	55.7
Naphtha/refinery gas	41.2	55.6	384.4	445.4
Natural gas	—	20.4	—	20.4
Total	142.8	76.0	364.5	583.3

[Chem. Age of India, 17 (1966), 3, 141]

TABLE 7—PRODUCTION, DESPATCHES AND STOCKS OF
CALCIUM AMMONIUM NITRATE DURING 1965

(m. tonnes)				
Month	Opening Stock	Production	Despatches	Closing Stock
January 1965	16,735	46,890	52,762	10,863
February	10,863	50,590	45,785	15,668
March	15,668	46,656	45,210	17,114
April	14,177	50,950	49,072	16,055
May	16,055	46,507	52,823	9,679
June	9,981	44,590	48,039	7,511
July	7,511	54,451	52,997	8,965
August	9,702	44,367	50,235	3,834
September	3,834	51,053	43,714	11,173
October	11,173	43,110	40,600	13,683
November	13,683	38,358	37,034	15,007
December	15,007	42,887	52,418	5,476
Total	—	560,409	570,689	—

Note: Certain differences between closing and opening stocks are due to stock taking adjustments.

[FAI Inf. Serv., 7 (1966), 8, 10]

TABLE 8—ESTIMATED FUTURE REQUIREMENTS OF HYDROGEN
FOR NITROGEN FERTILIZERS IN INDIA

Year	Fertilizer target	Hydrogen Tonnes	Target per year 10^6 Nm^3
1965-66	800,000	201,000	2,258
1970-71	2,400,000	604,800	6,770
1975-76	4,000,000	1,008,000	11,300

[Chem. Age of India, 17 (1966), 3, 142]

TABLE 9—AVERAGE HYDROGEN CONSUMPTION IN U.S.
REFINERY HYDROTREATING OPERATIONS

Feedstock for Treatment	Hydrogen Consumption, cft./bbl.
Feed to Catalytic Reformers	30
Solvents	10-15
Middle Distillates	100-150
Heavy Naphtha	100
Gas Oil	200
Heavy Heating Oil	50
Lubricating Oils	100
Waxes	100

[Chem. Age of India, 17 (1966), 3, 142]

TABLE 10—HYDROGEN REQUIREMENTS FOR SOME REFINERY
AND PETROCHEMICAL OPERATIONS*

Feedstock	Process	Hydrogen Requirement
Inferior Kerosene	Hydrogenation	234 Nm^3 /ton feedstock
Aromatic Extract	Hydrogenation	400 Nm^3 /ton feedstock
Atmospheric Residue	Hydrocracking	1200-1700 SCF/bbl.
Deasphalted Residuum	"	920 SCF/bbl.
Straight-run and cycle gas oils	"	2400-2600 SCF/bbl.
Shale oil	"	1900 SCF/bbl.
Coal tar	"	3000 SCF/bbl.
Xylenes	Isomerization	47 Nm^3 /ton feed.
Toluene	Hydrodealkylation to benzene	1030 Nm^3 /ton feed.
Benzene	Hydrogenation to cyclohexane	2500 Nm^3 /ton feed.

*Based on process evaluation and some experimental studies at I.I.P., Dehra Dun.

[Chem. Age of India, 17 (1966), 3, 142]

TABLE 11—COST OF MAJOR ITEMS IN HYDROGEN
PRODUCTION, %

	Natural gas Reforming	Naphtha Reforming	Fuel Oil Partial Oxidation	Coal Gasification	Electrolysis of water
Feedstock	43.0	32.6	21.7	32.4	0.0
Energy	27.4	34.8	28.8	1.95	87.5
Others	29.6	32.6	49.5	65.65	12.5
	100.0	100.0	100.0	100.0	100.0

[Chem. Age of India, 17 (1966), 3, 174]

TABLE 12—MANURIAL VALUE OF DIFFERENT MANURES

Name	Nitrogen, %	P_2O_5 , %	K_2O , %
Bio-fertilizer	1.8-2.4	1.0-1.2	0.6-0.8
Farmyard Manure	0.4	0.2	0.4
Compost Rural	0.6	0.5	0.6
Compost Urban	1.0	1.0	1.25
Green Manure	0.5-0.7	0.1-0.2	0.6-0.8

[Res. & Indus.,—11 (1966), 25]

Introduction to Understanding of the Theory of Universal Spherical Wave of the “Energy Field of the Universe and Atom”

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In this article an attempt has been made by the author to describe briefly the theory of universal spherical wave of energy field as propounded in previous works¹⁻³. The theory as a single unified concept may prove to be of universal applicability to explain any phenomenon capable of independent equilibrium existence including the manifestation of the inanimate universe. The theory has been applied to explain the various fundamental laws of modern science as well as scientific observations which lack satisfactory explanation. The author has shown that the postulates of the works are very similar to, if not identical with, the postulates of *Sankhya* science developed in ancient India. Since the approach to the theory is completely unorthodox and the terminologies of modern science which may convey different significances in the approaches have been used, the author has made an attempt here to introduce the subject, briefly emphasising the various significances and the basic ideas.

The basic concept of the theory of Universal Spherical Wave¹⁻³ is that if something would evolve out of nothing, which would subsequently establish an equilibrium configuration of existence, there must be a cause; the cause is defined as the fundamental dimension creating the evolution. In its purest isolated state of existence, the fundamental is of infinite magnitude of intensity. In the evolved manifestation it assumes finite magnitude, both of intensity and of size of configuration. During this action it creates simultaneously a derived opposite dimension as a reaction to the first action, as well as two other opposing associate dimensions; one to contain the fundamental and the other to contain the derived opposite. The four-together give the evolution a finite configurational concept, in which the four dimensions in varying magnitudes and properties establish equilibrium. While starting the evolution, the fundamental creates four-cornered positions of a regular tetrahedron which are occupied by the derived dimensions, and the fundamental assumes the position at the centre. The four dimensions are: two pairs of two opposites, establishing the equilibrium existence of the configuration, which symbolically could be expressed as:

$$+/- = -/+$$

In the finite energy, matter, space and time manifestation of the inanimate universe, the above equilibrium would be represented as: $E/M=L/T$ or ET/ML = some constant of equilibrium, where E is the dimension of energy, M of matter, L of space and T of time.

Incorporating the postulates of the theory that space L is four directional and time T is three directional, the relationship would be expressed as: $[(E/M) \times (T/L)] = L^4/T^3 \times \text{constant of equilibrium}$ or $E/ML = L^4/T^4 \times \text{constant of equilibrium}$.

The symbols have the usual dimensional significance; energy is fundamental and the rest are derived. These are, however, contrary to conventional concept of dimensions in which M, L and T are *three fundamental dimensions*. In the present case E is the *only fundamental dimension* and all the rest are derived ones. The magnitudes of the constant could be anywhere *between nil and infinity* depending on the magnitude and nature of associated variability. Only fundamental dimension can assume infinite magnitude of intensity; the rest cannot. They can only assume magnitudes ranging from the highest to the lowest finites. It is to be noted that magnitudes of dimensions can be expressed in terms of the size of the configuration or their intensities. The direction of change of magnitude of intensity is opposite to that

of the size of configuration. These are the essential premises of the theory to start with.

The basic problem is to uncover the mechanism of evolution of something in the background of nothing. The postulates in the theory start with the assumption of a hypothetical situation in which there exists nothing either in perception or in conception; a situation of perfect emptiness or nothingness. Let us imagine that from this background of nothingness a manifestation occurs, evolves and develops into an equilibrium concept of some configuration. Imagine the energy matter universal manifestation in this approach.

If in the background of nothingness some manifestation has to occur, it must have a cause. Before the manifestation occurs the cause cannot be defined; the cause cannot be expressed by any property since the cause existed prior to the manifestation in indescribable nothingness. The designation of the cause, which existed before the manifestation in a medium of nothingness, has been termed in the theory as the fundamental dimension, the existence of which cannot be described by any associated dimension, configuration or property. This is an abstract but infinitely pure state (in terms of intensity) of fundamental dimension in conception. It is only when the fundamental dimension starts creation of manifestation (i.e. when it starts forming finite configuration by associating with it certain other objective or comprehensible derived dimensions) it can assume a form of finite magnitude of the configuration. Thus while energy as the fundamental dimension, as the cause, starts causing the formation of manifestation of the inanimate universe, it associates with the other conceivable dimensions like matter, space, variability, etc. Energy in an isolated state of existence of infinite purity in the present theory is a fundamental dimension, capable of assuming infinite potential as the cause of the inanimate matter energy universal manifestation. The fundamental dimension, energy, associated with other dimensions like space, matter, time, variability significances, etc. constitutes the inanimate universe and presents it in an objective or finite form. When it existed in its fundamental state, it was an indescribable or Absolute state of the dimension-energy. When this fundamental dimension, energy, would start creating the manifestation of the matter energy inanimate manifestation, energy would make a start from the position of a point source where its intensity would be of finite highest order; it would be in association with least but finite magnitude of other induced dimensions like space, variability and matter significances. The energy assuming a point of position of

intensity of finite highest order would generate simultaneously opposite reactions through matter dimension due to its own action. The derived dimension-space is the containing dimension of energy. The one position of energy at the start simultaneously, by its own action, generates four positions of reaction as matter significance, each with least variability and least intensity of matter as well as least associated space. This is the start of the manifestation of evolution of energy-matter configuration. (It would look when projected on the plane of paper as shown in Fig. 1).

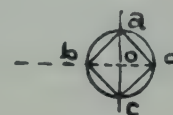


Fig. 1.

At the centre O, E has finite highest intensity. Intensity of M tends to nil. Magnitude of L tends to nil. T tends to have infinite magnitude in configuration, and variability tends to nil.

The energy emanates from the source at the centroid O radially towards the four generated positions of matter, a, b, c, d maintaining perfect isotropy (in radial direction from the centre). In the evolved tetrahedron of four derived positions of matter dimensions, with respect to each position in the evolved tetrahedron, the other three are identical. Thus, the evolution of the manifestation starts in a perfectly isotropic manner with respect to the central position as well as any evolved position vis-a-vis the other three. Now, when E assumed a position of point, the energy was associated with least magnitude of space containing energy and with four matter positions of least magnitude of intensity. But with the progress of the manifestation, the original position of one energy, with four matter positions, undergoes expansion with increasing magnitudes of associated dimensions of space and variability and matter significance of the positions. Thus, during the process of evolution of the manifestation from the centre, the four positions which were originally condensed to one, while expanding and describing expansion of space in four radial directions, progressively change with increasing magnitude of variability. The energy, thus, while describing the progressive evolution of the manifestation radially assumes a concept of increasing magnitudes of spherical surface (mentioned in the theory as Equipotential Spherical Surface). Space contains energy; at the centre space magnitude

was least, energy intensity tending to infinity and positions of matter were with least intensity and least variability. As the positions of matter at the evolved equipotential spherical surfaces go further away from the centre, energy intensity at the spherical surface decreases and matter intensity of the positions increases. With respect to the centre, the magnitude of space of the developed manifestation could be recognized in terms of the magnitude of the radials. The dimension L thus constitutes the concept of space as radius from the centre of evolution of the spherical energy-matter evolutionary field retaining tetrahedral configuration.

Configuration of the Fundamental Dimension

A point of great significance about the fundamental dimension is its imaginary nature of configurational existence in its abstract state. The fundamental dimension in its abstract state of existence possesses infinite intensity. In this state the fundamental does not associate with any other dimension i.e. the fundamental in this state is completely free from any association whatsoever. Thus, in this abstract state, it is in an infinitely pure state of existence. In the finite manifestation, however, from this state, the fundamental must start to assume finite tetrahedral configuration by associating finite magnitudes of other derived dimensions in the configuration. Thus, it may be construed that the fundamental in its abstract state of existence also has tetrahedral configuration which in that state is only imaginary and none of the 4 positions are associated in any way with any other dimension. The configuration of the fundamental dimension is an imaginary regular tetrahedral concept of nil magnitude (i.e. infinitely small magnitude of size), the centre of which is occupied by infinitely pure fundamental dimension, and the 4 positions of which contain nothing. When the imaginary vacant positions of the configuration from that state associate with some derived dimension, the manifestation of finite evolution starts and becomes the universal manifestation by progressively increasing in magnitude till the evolution, in the form of spherical wave, comes to an end at an imaginary boundary of the wave, where the fundamental falls to nil magnitude in intensity or purity and the derived assumes infinite magnitude.

Energy manifestation is recognized as space and matter position by its containing dimension-time as orbit (say, orbit of three with respect to one at the evolved tetrahedral surface). While energy describes space radially in four directions with respect to one at the centre, matter in the evolved tetrahedral con-

figuration describes time orbit of three with respect to the fourth position. Thus universal space, according to this theory, is four-directional (conventionally four-dimensional) and time pertaining to matter positions is three-directional (i.e. three-dimensional). Conventionally, it is said that space has three dimensions and time is the fourth dimension. This obviously could refer to one "curved space" in the universal manifestation, as Einstein put it. Or as Narlikar-Hoyle⁴ put it, as "orbit in straight line disturbed in space", obviously referring to relative orbital variations of matter positions. But in this theory, what we measure as space along a "curved space", i.e. at one equipotential surface of the universal manifestation, is actually the time (relative to matter) positions in the configuration along one equipotential surface in the universal spherical wave at constant magnitude of L .

When energy position was at the centre, the four positions of associated matter were of least intensity; when radially the positions disperse in space from the centre, correspondingly the matter potential of the positions increases with simultaneous increase of variability associated with the positions. Progressively, the various equipotential spherical surfaces of four positions with increasing variability would develop more spherical surface areas in succession at which the energy distribution will progressively diminish in intensity but matter associations with the individual positions increase. There would thus be a stage when a spherical surface locus of the four positions would have magnitude of energy intensity numerically equal to the intensity of matter significance associated with individual position. This is the ABCD state of equality equilibrium spherical surface of the universal spherical wave of energy matter field, where variability associated with the positions would tend to assume the highest finite magnitude in the spherical wave such that at any point of location on this surface one position will be found to be present at any instant (Fig. 2).

Let us draw the figure up to the development of the equality equilibrium surface (as it would look when projected on the plane of paper).

At ABCD spherical surface, $L=T=E=M$; variability is maximum but continuous.

Inner Field Region (Homogeneous)

The universal energy matter manifestation developed into the equality equilibrium surface ABCD has equal magnitude of matter intensity, energy intensity, time and space. All the positions, within this region between

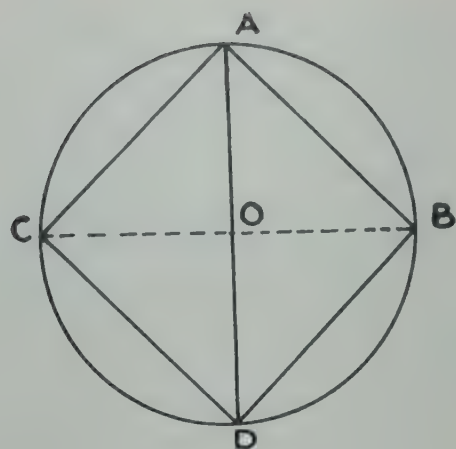


Fig. 2.

ABCD and the centre O, are associated with energy and matter as inseparable. They are associated with varying magnitudes of variability. Matter and energy dimensions up to the equilibrium surface have not segregated. At the equality equilibrium surface, the magnitudes of intensity of matter and energy have reached equality but the positions have attained variability which is maximum in the manifestation. The significance of this can be further explained as follows:

At the centre, the energy was of finite highest order of intensity, associated with space of least magnitude, and the four induced or derived positions of matter dimension were present with least variability and with the least interval of space between them but with time of infinite magnitude (which is imaginary because its magnitude of configuration at the centre is highest but intensity is least since its containing dimension is matter. It should be remembered that space intensity is energy and time intensity is matter). With the progress of evolution, the manifestation arriving at a spherical surface, at any radial distance from the centre, has the four positions with more developed matter significance and surface area with less intensity of energy than at the centre; the magnitude of configuration of T decreases but the four positions, due to increased variability, describe the spherical surface locus such that the probability of presence of any position at any point of the surface is instantaneous. Proceeding radially further in this way, at the equality equilibrium spherical surface ABCD, the positions would acquire equal magnitudes of intensity of matter and energy as well as magnitudes of time and space and maximum variability associated with them such that any of the four positions would find a probability of being present at any point of position at the spherical surface of equality equilibrium. The configurations (Figs. 1 and 2) are only figurative presentations be-

tween two limits at particular instant. If the dynamic aspect is associated, (incorporating actual directional path of positions), the figure would appear on the plane of paper as shown in Fig. 3. This has already been explained in Fig. 9 of Energy Field of the Universe and Atom² Part II. For the four positions starting at O during creation of space, their direction of change of positions from O to ABCD follow the curved radial lines, OA'A, OB'B and so on. From O, any of the four positions starts at the first instant in radial direction (with maximum radial space intensity and least orbital time intensity) which, with continuous change, ends up at the positions at the evolved spherical surface at right angles to the radius. For example, the positions describing OA'A start from O—first radially towards A (OA) i.e. same direction as OA having nil angle with OA, but, with progress of expansion in space configuration, the position cuts the other radials at progressively larger angles at greater distances till it arrives at the position A at the evolved tetrahedron with direction of motion along the evolved spherical surface at right angle to the radius. Similar is the description of paths by the other positions.

Outer Region of the Spherical Wave (Heterogeneous)

When, according to this theory, the manifestation develops further beyond equality equilibrium, segregation of matter and energy starts. Matter and energy at the equilibrium surface of equality had equal in-

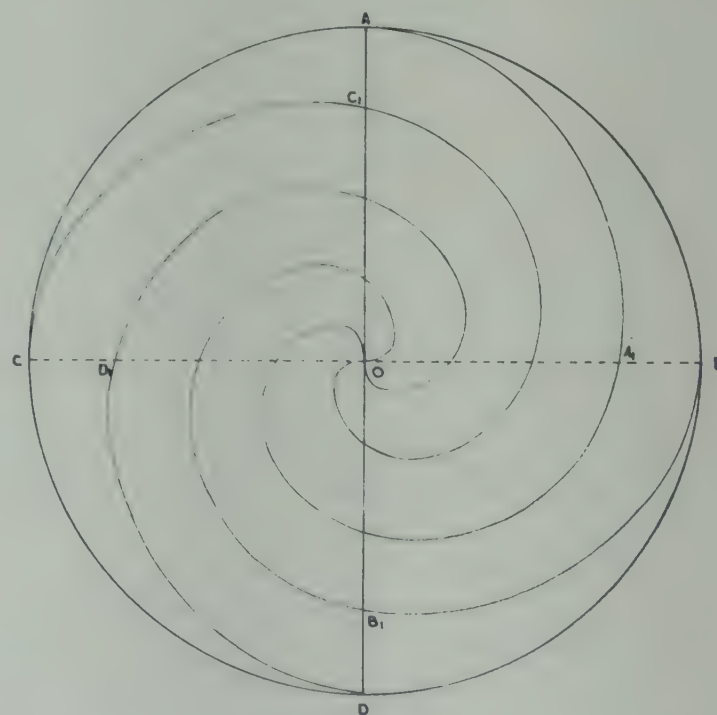


Fig. 3.

tensities (relatively) to start with. From that surface outward towards the boundary of the spherical wave, the field space magnitude would start increasing (with four cones opening outwards), whereas the segregated matter dimension as atomic mass would progressively increase in intensity (with four cones converging outwards) till the boundary of the spherical wave would be formed by four matter positions at W, X, Y and Z of finite highest order of intensity where energy intensity would be reduced to nil. The energy field of the universe of the outer field would take a figurative configuration (Fig. 4).

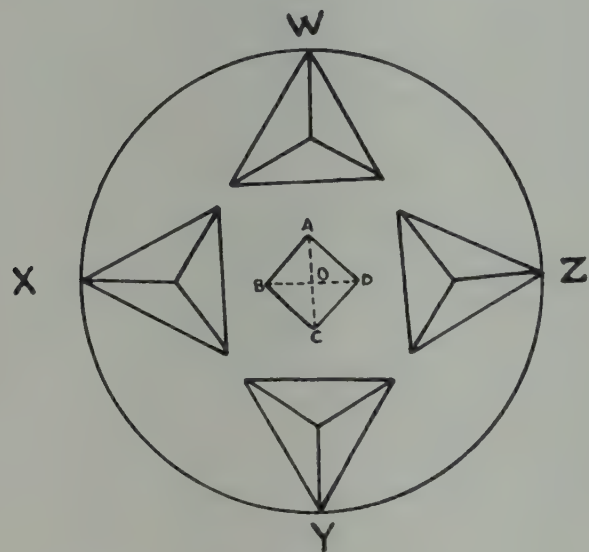


Fig. 4.

At boundary WXYZ

- E=nil intensity
- M tends to infinite intensity
- L tends to infinite magnitude
- T tends to nil magnitude
- Variability to Nil

To understand the configuration of the spherical wave and the various combinations of dimensions relative to various states of equilibrium existence, it is important to differentiate between the two opposite significances of the term 'magnitude'. (The differentiation is repeated below for the sake of emphasis). The 'Magnitude' of anything can be expressed in two ways, either in terms of its size or in terms of its intensity of content. The magnitude of the dimensions, constituting the universal spherical wave, can be expressed similarly. For dimension Matter, for example, in the universal spherical wave, at the boundary its magnitude of intensity is highest but it is in association with the biggest spherical surface of the space-time configuration, which has least energy intensity. At the centre, the

magnitude of matter intensity is least and energy intensity is highest. The magnitude of the size of the configuration is least at the centre. Since the configuration as such is constituted of space and time, in which space is radial and time is orbital, the intensity of time is least at the centre and highest at the boundary. Similarly, intensity of space is highest at the centre and least at the boundary. This requires further clarification since the statements may appear to be contradictory. Time is the containing dimension referring to matter while space is the containing dimension referring to energy. Thus, when time of matter configuration is taken the configuration of time pertaining to individual matter positions is least at the boundary at positions W, X, Y and Z, where matter intensity is highest. Similarly, for matter at the centre, its intensity is least and its time intensity is also least, although the configurational time would have highest configurational magnitude, but it is not realized in the configuration. Similarly, space intensity is highest at the centre where energy intensity is highest but the magnitude of space of configuration is least. At the boundary, magnitude of space of configuration is biggest; but the space and energy intensities are least.

Thus, in the zone within ABCD of the configuration of the spherical wave, as constructed in Fig. 3, at the centre, magnitude of space of configuration is least but its intensity (i.e. radial effect) is highest; Time intensity (orbital effect) is least and configurational time could be highest; at the boundary WXYZ, magnitude of configurational space is highest, space intensity is least, and magnitude of time intensity highest but magnitude of time in configuration pertaining to matter is least. Thus, that $L/T=O$, both at the centre and the boundary, should be understood in this context. For example, the values of L/T , expressed as magnitudes of size of configuration at the three extreme states of the wave, are as indicated in (a) below and in terms of magnitudes of intensity as in (b) below.

(a) Magnitude of size of configuration

	Boundary State WXYZ	Equality equilibrium state ABCD	State at the Centre O
$L/T=$	Nil	1	Infinity

(b) Magnitude of Intensity

$L/T=$	Infinity	1	Nil
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Strictly speaking, so-called matter and energy are perceived in reality as intensity of time and intensity

of space in space-time configuration respectively in the universal spherical wave configuration and thus the concept of dimensions of matter and energy as having some concrete substance is only imaginary. The universal spherical wave, as such, is an equilibrium of space and time between their magnitudes of configurational size and their magnitudes of intensities.

In the outer field the magnitude of variability, which reached maximum at the equality equilibrium surface ABCD from the centre, progressively decreases towards the boundary so that the matter positions at W, X, Y and Z at the boundary are of highest intensity but having least variability (least dynamic). The magnitude of variability, in the spherical wave is least at the centre as well as at the boundary, whereas it is maximum at the equality equilibrium surface.

Within ABCD, intensity of E varies in opposite direction with configuration space magnitude, intensity of matter, magnitude of variability, and with intensity of time. Outside ABCD, matter intensity varies in opposite direction with intensity of space, configurational time, and energy intensity. In the limits set by our perception and conception, when magnitude of intensity is highest, magnitude of configuration is least and vice versa. This point is important in understanding the implications of the theory of spherical wave in proper perspective.

From the figure, it would be observed that the four (tetrahedral) positions of energy/matter retain the tetrahedral configuration at all the spherical equipotential surfaces in between the centre and the boundary. The outer field from the four triangular faces of the evolved tetrahedron at ABCD to the boundary, has been termed as the 'potential field' as well as the 'heterogeneous field'. Each triangular face of three positions describes T and converges towards one point of position (at W, X, Y or Z) at the boundary of highest matter potential where T tends to nil. On the other hand, the space magnitude, from each face of three positions from the equality equilibrium, progressively expands till at the boundary spherical surface, it tends to assume finite highest magnitude and energy intensity tends to reduce to nil.

It should be remembered that matter and energy, within the equality equilibrium, maintained indistinguishableness and inseparability; in this theory, that state in the energy-matter field is termed as 'homogeneous' or 'kinetic' field. That state was illustratively likened (vide Part I¹, page 166) to a superheated vapour state or a supersaturated solution. On the other side

of the equality equilibrium surface, the field manifestation of matter-energy was likened to crystallization from a solution or a condensing vapour in which crystals are segregated from the mother liquor and condensed drops are segregated from the vapour phase respectively. The concentration of mother liquor or vapour phase radially becomes depleted towards the boundary while the condensed crystals, however, increase in intensity towards the boundary.

In Fig. 4 the outer field of the spherical wave between the equality equilibrium ABCD and the boundary WXYZ is in reality a combination of 4 segregated regular tetrahedrons attached face to face with the 4 triangular faces of 4 positions of the central tetrahedrons. Projected on the plane of a paper this would look as in Fig. 5(a). The central tetrahedron, within the equality equilibrium ABCD, represents the homogeneous zone of energy matter field. The 4 outer tetrahedrons, together with intervening space between the boundary spherical wave surface through WXYZ and ABCD, would give the significance of heterogeneous zone of the spherical wave. The whole configuration of 5 tetrahedrons as in Fig. 5(a) makes the simplest equilibrium configuration of the universal spherical wave. In Fig. 5(b), the same has been shown by way of clarification, segregating the 5 tetrahedrons. In Fig. 5(c), the same has been depicted with indication of the various stages involved in the evolution of the wave between the central point and the boundary, indicating variations of magnitudes of the various dimensions constituting the spherical wave.

Although the simplest configuration of the spherical wave, considered as one in equilibrium of one central tetrahedron face to face with 4 outer ones, has been indicated as the equilibrium configuration of the universal spherical wave in Figs. 5(a), (b) and (c), so far as the central tetrahedron is concerned, it can only be one, its four faces being just engaged with 4 outer tetrahedrons. Each of the outer tetrahedrons in the heterogeneous zone, however, can take 3 more tetrahedrons for its three unfilled (or unsaturated faces) to complete the configuration. In other words, instead of 4 main tetrahedrons in the outer field, there could be 16 tetrahedrons (4 groups of 4) fitted in the outer zone. Within the boundary WXYZ, no more tetrahedrons can be fitted in. Thus, the maximum number of tetrahedrons, which would be required to complete the configuration of the spherical wave, would be one central tetrahedron forming the homogeneous field of the wave and 4 groups of 4 tetrahedrons, i.e. 16, forming the heterogeneous field. Thus, one central

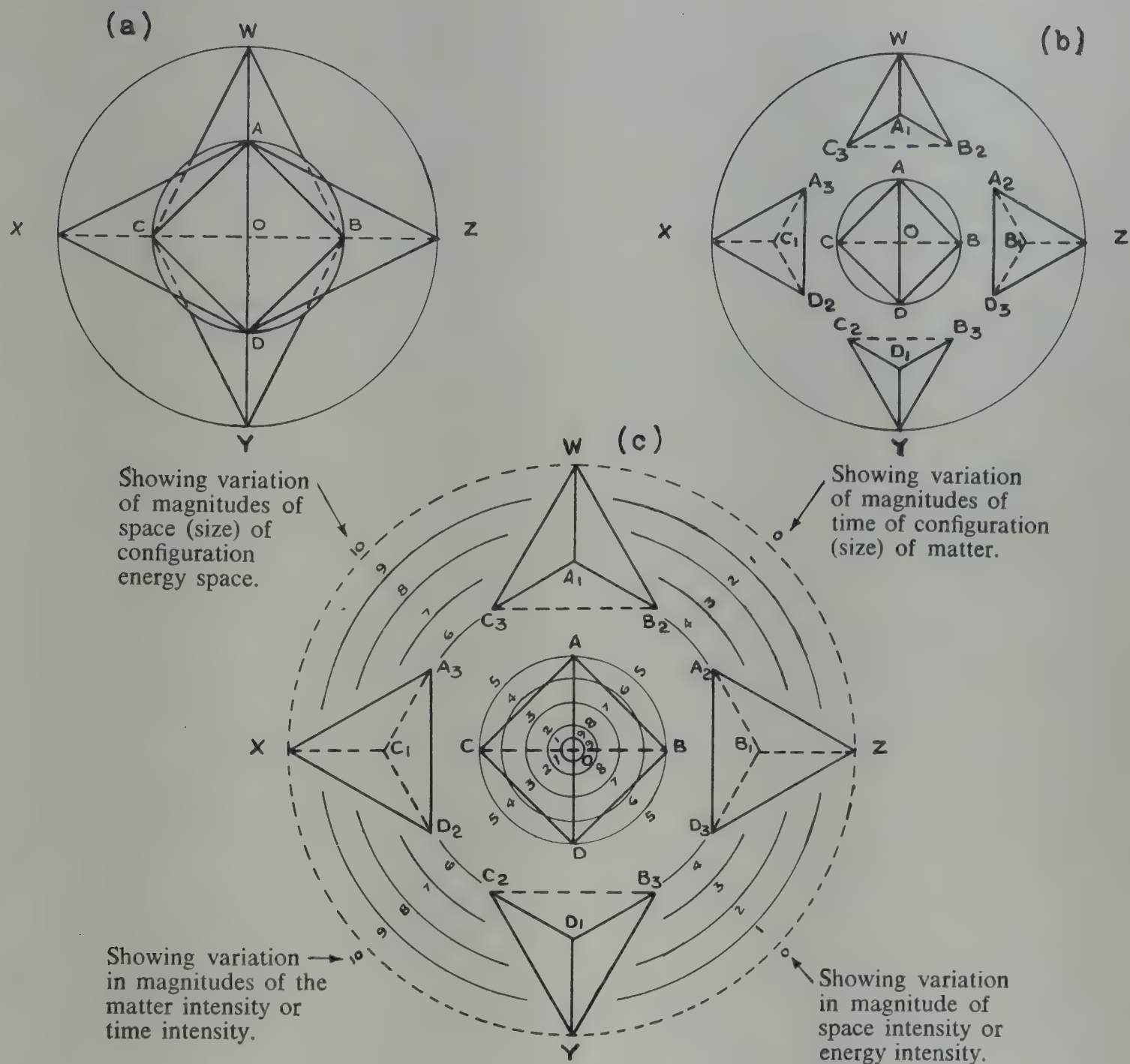


Fig. 5.

Fig. 5(a) represents a central tetrahedron ABCD together with four tetrahedrons placed face to face at the four triangular faces of the central tetrahedron. The central tetrahedron represents the homogeneous phase where the fundamental and derived dimensions exist in one inseparable form. The four outer tetrahedrons, with the intervening empty space, constitute the heterogeneous field of the Universal Spherical Wave, between ABCD and the boundary Spherical Surface passing through the apex positions W, X, Y and Z of the four tetrahedrons.

In Fig. 5(b) the same configuration in Fig. 5(a) has been shown by separating the four outer tetrahedrons from the inner one.

In Fig. 5(c) the same Universal Spherical Wave is shown, for clearer understanding by incorporating the spherical surfaces in between the centre and the boundary, four in the homogeneous and four in the heterogeneous zones.

tetrahedron, opposed by 16 tetrahedrons, would establish the equilibrium and would constitute the universal spherical wave.

It should be noted that whereas the central tetrahedron, during evolution, would engage 4 tetrahedrons face to face in opposition in 4 directions from the central point, each of the 4 outer tetrahedrons, having one face already engaged with one face of the central tetrahedron, can engage the remaining 3 vacant faces only with 3 more tetrahedrons. The significance is that while the evolution takes place radially from the centre in 4 tetrahedral direction, the development occurs in 4 directions and in the outer zone each of the four tetrahedrons, in figure 5, has lost one degree of freedom and been left with only 3 degrees of freedom to operate, i.e. each can attach 3 more tetrahedrons to it. If in the former case the evolution from the centre was 4 directional, evolution in the latter case is 3 directional.

Just as was done in Fig. 3, incorporating the significance of variability associated with the four positions starting in four directions from the centre through the equality equilibrium surface ABCD, outside ABCD components of three in one direction from each of four faces of three positions converging to four points of positions at W, X, Y, and Z at the boundary has been shown in Fig. 6. The directions, tracing evolution of positions up to ABCD, are diverging and from ABCD, continuity of the directions of positions is

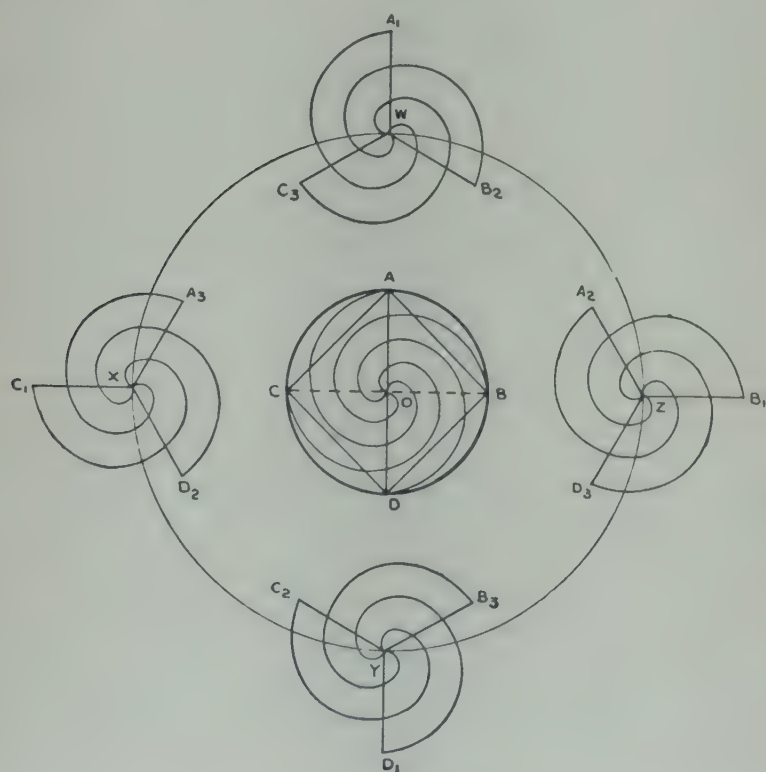


Fig. 6.

maintained by four components, each of three, from four evolved positions ABCD, towards four positions at the boundary WXYZ. It is to be explained that the four outer tetrahedrons are formed from the four sets of three components, one each from four faces of the central tetrahedron ABCD, in which each of the positions A, B, C and D are split into three directions so that each of three positions of four faces ABC, BCD, ACD and CDA, after making converging spiral of T, ends up at the boundary at points of positions W, X, Y and Z. It may be seen that each position of ABCD retains influence in three evolved tetrahedrons.

All these configurations of evolution were explained in Fig. 9 of the Energy Field of the Universe and Atom Part II. The relationship of energy-matter evolution from the centre up to the equality equilibrium in terms of L and T in the theory is represented by $E/M/L = (L/T)^4$, which is applicable during expansion of space from the centre towards ABCD. While the three positions in the outer field are converging towards one position, say Z, the energy matter variation would be

governed by $\frac{ET^2/L^2}{ML} = L^2/T^2$. In this, the dimension

energy has degenerated from E to ET^2/L^2 .

The problem is how to express the concept of the theory in terms of recognisable quantitative and perceptible dimensional configuration. Any finite manifestation, caused by a fundamental dimension, must arrive at an equilibrium state of existence in which the fundamental, in association with derived dimensions, should exist in equilibrium attaining certain magnitudes. The four dimensions should, therefore, be co-existent to form the equilibrium states of existence.

In terms of energy, matter, space and time dimensions, the equilibrium states must be formed between the magnitudes of states of the fundamental dimension and the derived opposites. If we designate the fundamental as the positive and the derived dimension as the negative, then these two are opposites. Similarly, the containing dimension of the fundamental, which also is opposite to its own, and the containing dimension of the derived is also opposite to that of the latter. The two containing dimensions themselves are opposite in direction of magnitude to each other and these must be associated in determining the equilibrium state. Thus the equilibrium state turns out to be a concept of equation between the two opposite pairs of two opposites; the equation can be represented symbolically as:

$$+/- = -/+$$

This gives the essentials of the concept of the equation, having tetrahedral configuration. On the left hand side (+) refers to fundamental dimension and (—) refers to derived dimension. On the right hand side, (—) refers to the containing dimension of the fundamental and (+) refers to the containing dimension of the derived. If these dimensions are designated by energy, matter, space and time, the left hand side would be represented by E/M and the right hand side by L/T. Re-arranging in terms of these dimensions, the equation reduces to:

$$ET/ML = \text{equilibrium constant}$$

In order to evaluate this constant, we have first to assign magnitudes to the dimensions. Directions of magnitudes of a dimension could be in terms of intensity or in terms of extent of size of two opposites in significance. Only the fundamental dimension in its absolute state can assume infinite magnitude of intensity. In the created manifestation, it only assumes finite values wherein infinity or nil is not permissible.

If energy and matter would be expressed as intensity and L and T would be expressed in terms of their magnitudes of extent in configuration, then the equation ET/ML can be in a state of equilibrium between (+) infinity on the one hand and (—) infinity on the other. In a state, where all the dimensions are of equal magnitude, equilibrium state becomes one of unity. Thus, the above values of constant would range from 1 to \pm infinity. This is one way of expressing the theory.

The manifestation at various states of development must exist at magnitudes of particular state of equilibrium (i.e. magnitude of equilibrium constant). For establishing equilibrium according to this theory, the manifestations require action and reaction due to these four dimensions balanced isotropically between two opposite pairs each of two opposites and the state of equilibrium is determined by the magnitude of equilibrium constant for that state. In terms of magnitudes, energy is opposite to matter and space opposite to Time. Thus E and L are opposites, as also M and T. For equilibrium

$$E/M = L/T$$

or $ET/ML = \text{Eq. constant}$

The value of the constant can be anywhere between nil and infinity depending on the magnitudes of the dimensions. Finite magnitudes of the dimensions must be between the following: E=infinity, M=nil and E=nil, M=infinity. In tetrahedral isotropic evolution,

there can be only nine finite equilibrium states. If M would be allowed to assume higher magnitude than in the 9th state, energy magnitude would tend to be nil which would result in end of the completion of the concept of one evolution because magnitude of fundamental then becomes nil. One evolution would be designated by the symbol O, wherein lies the significance of evolution of numbers relating to states. Figuratively, this would be represented as:

E	9	8	7	6	5	4	3	2	1
M	1	2	3	4	5	6	7	8	9
T	9	8	7	6	5	4	3	2	1
L	1	2	3	4	5	6	7	8	9

Vertical columns determine the equilibrium associations of magnitudes of the dimensions. Other associations would not be permissible for isotropic equilibrium.

The value of equilibrium constants of ET/ML could lie anywhere ranging from 9 to 1/9. If matter could rise in magnitude of finite existence at the 10th stage, where the fundamental E would be nil, that would result in the end of one evolution of matter-energy.

The theory stipulates that the fundamental dimension at the start was of highest intensity associated with least derived and formed the centre of the spherical wave or centroid of a tetrahedral configuration, from which four derived positions vary outwards during which the fundamental and derived exist as one. The state of oneness of two opposites expands, creating increasing space magnitudes associated with increasing magnitude of variability till it reaches the state of equilibrium of unity of constant or equality of dimension (at ABCD) at which energy and matter intensities equalize, and the constant of the equation assumes a value of unity. In the configuration of the theory in the field up to this extent, energy exists in equilibrium with matter as one in one configuration. With further expansion of space energy, matter segregates out from the energy phase till at the boundary of the spherical wave, intensity of energy at the boundary of the spherical wave would tend to fall to nil and four matter positions would tend to rise in intensity to infinite magnitude.

In this description of the configuration, the tetrahedral significance must be retained. The creation of space from the centre up to the equality equilibrium was in four directions of space whereas the four matter positions from the boundary towards the centre have each three associated directions of time.

In Part I of "Energy Field of Universe and Atom", the entire treatment has been based on the varia-

tions of the properties of the dimensions just along spherical surfaces at various radial positions from the centre to the boundary (without incorporating the tetrahedral concept). In Part II, those variations have been qualified incorporating the tetrahedral concept; the essentials are the same in both the approaches.

It is now necessary to find out the conflict between the postulates of this theory with the basic concepts of Modern Science. The first aspect is the question of dimensions. In Modern Science, matter, space and time are three fundamental dimensions; the other dimensions like energy, momentum, force, etc. are all of derived status. In this relationship in equilibrium existence, no finite configuration has been ascribed.

In the present theory there is only one fundamental dimension which is energy. All the rest are derived dimensions. Only the fundamental dimension can assume magnitude of infinity and that too at its absolute state of existence which is beyond conception, and the rest only possess magnitudes in the manifestation which necessarily are finites. In Modern Science, no such qualification or stipulation exists in respect of dimensions.

In this theory, space is energy though in the opposite sense in magnitude; space pertaining to energy has four directions while time pertaining to matter has three. Association of variability is continuous in one zone of evolution in the manifestation and discontinuous in the other, the former referring to the zone between the centre and the equality equilibrium, and the latter to the zone of the energy matter field between the equality equilibrium and boundary. No such difference is reckoned with in Modern Science. In Modern Science, space is an empty entity called vacuum.

We are living in our perception, conforming only to one state in universal manifestation pertaining to the heterogeneous region and that too along one spherical surface context. In the matter-energy universe, segregated matter manifested in phenomena like the quasars, nebulae, galaxy, planets, etc. are perceived in progressive stages of evolution in the universal manifestation starting from equality equilibrium. The concept of matter, associated with energy in one form within the equality equilibrium surface in the homogeneous zone of the field, cannot be perceived visually, but in all the manifestations, it would be in the form of radial force due to pressure of expansion of space-energy with falling potential of energy. Beyond the equality equilibrium, in the outer space where matter is segregated out of the space and is distinguishable from the space, radiating objects like nebulae, galaxy,

quasars, etc. start and first matter synthesis as hydrogen, neutron, etc. begins. In the equipotential surfaces, further away from ABCD towards the boundary, all manifestations will have more developed matter entities such as H, He, Li, C and so on in accordance with the order in the conventional periodic table of elements following the law: $ET^2/L^2/LM=L^2/T^2$.

In the universal law, however, at the equality equilibrium, energy-matter with equal intensities starts with maximum space as T of three positions. The significance is that the lightest distinguishable elements like hydrogen first formed would have association of lower space magnitude of higher energy intensity and, as the atom develops at the outer equipotential surfaces further from the equality equilibrium, the atomic magnitudes also should reduce in their time orbit i.e. equivalent to lower radius till at the boundary the matter atoms would have the least T which would be equivalent to the least atomic radius and the highest matter intensity in time but in association with the largest space of least energy intensity. The equilibrium space energy intensity, with which the atoms at the various stages of development would remain in equilibrium, can be realized from the configuration of the energy field. At the equality equilibrium, the atom describes T with three positions and occupies the whole of one face of tetrahedron ABCD with little space outside the atom. When the development of the atoms in equilibrium with the space at equilibrium at other spherical surfaces proceeds with increasing mass intensity towards the boundary, the ratio of mass intensity to surface area occupied by equilibrium field energy space, becomes more till at the boundary surface, the ratio of the atomic intensity in time to energy intensity in field space tends to infinity. From this, the significance that atoms at the regions of the energy field towards the equality equilibrium will have maximum atomic size, with less magnitude of space of higher energy intensity associated, would be realized. The matter-energy magnitudes at a spherical surface nearer to the boundary would have atoms more intensive in mass, less in their time magnitude; the field energy association would have bigger magnitude of spherical surface space with less intensive energy in it. This can be illustrated in conventional terms by hydrogen gas associated with space of higher energy intensity and less mass and a heavy gas like chlorine having higher mass content in equilibrium association of more space with less energy intensity. In the universal context, the possibility of development of different atomic radii can thus be noted.

Basic Law (Equation) of Evolution of Energy Matter Spherical Wave

The four-dimensional equation for evolution from centre to the positions in the evolved tetrahedron in homogeneous phase would be as has been shown in the theory: $E/M \times T/L = \text{equilibrium constant}$.

Associating four directional space evolution of E with three directional time of M, the above equation becomes: $E/M \times T/L \times T^3/L^4 = \text{eq. constant}$.

$$\text{Or, } (E/M)/L = L^4/T^4 \quad \dots \text{ (Case I)}$$

(E/M) at space and time magnitudes of L and T respectively. Equilibrium constant is assumed as unity. Actually this could vary between 0 and infinity. This is similar in significance to equation on pages 32 and 40 of "Energy Field of Universe and Atom" Part II.

In this², M is a property of E, indistinguishable and inseparable from it. When E and M would be distinguishable and separate, E would assume the dimension ET^2/L^2 which is the conventional matter (actually it is matter energy), say, M_o . M retains same significance as before, but now it is a property opposite to M_o instead of E in the previous case.

$$\text{Thus } (M_o/M)/L = L^2/T^2 \quad \dots \text{ (Case II)}$$

If M signifies property as momentum, in the present case it connotes the momentum of the electron and in the previous case M the pressure due to E from the centre.

In case (I), the relationship was applicable within ABCD i.e. between the centre and the four positions of the evolved tetrahedron ABCD varying with full T.

In the second case, it is applicable outside ABCD, between two opposite tetrahedral positions varying with half T, retaining their common center. In the former case, direction of increase of L/T is outward from the centre; in the latter, direction of decrease of L/T is towards apex positions.

In case (I), M and E positions of highest magnitude lie on the spherical surface at four tetrahedral positions A, B, C, D and the centre respectively. In case (II), M_o and M of highest magnitude lie at two opposite apex positions of 8 positions of a cube. In the former case, gravitation of M is outwards from O, and in the latter gravitation of M_o is inwards towards apex positions of highest M. Direction of increasing magnitude of variability is outward in case (I) and the opposite in (II), (Variability is continuous in the former and intermittent in the latter case).

In the former case, conversion of M to E is direct and in the latter, conversion of M to M_o comes first

and M_o to E subsequently, by dissociating T^2/L^2 through association of L^2/T^2 ($ET^2/L^2 \times L^2/T^2 = E$ wherein lies the significance of Einstein's equation $mc^2 = E$).

Conventional Gravitational Equation

Comparing the above with the realization of modern science, the conventional gravitational equation is expressed dimensionally in pages 20-21 of author's previous study 'Variable Velocity of Light'⁵ as follows: $M_1 L/T^2 = M_2 M_3/L^2 \times (\text{const. of gravitational equilibrium})$. Putting $M_1 = ET^2/L^2$ and assuming all Ms have the same dimensions but different magnitudes and the constant as unity, then

$$E/L = L^4/T^4 \quad \dots \text{ (Case III)}$$

$$\text{or } M_1/L = L^2/T^2 \quad \dots \text{ (Case IV)}$$

Comparing case (III) with (I) and case (IV) with (II), it is not difficult to find out what are missing in the equilibrium relationship in cases (III) and (IV) for the realization of the equilibrium between opposites. In case (III), the counterpart opposite of E as matter significance is missing. Similarly in (IV), the counterpart opposite of M_1 , having matter significance as ET^2/L^2 , is missing. These equations, however, have been found valid to explain manifestations in modern science, of course, within the range and limitations of observations in experiments with apparatus. Introduction of M factors in cases (III) and (IV), without changing the nature of equilibrium relationship, can be accomplished if the M factors to be introduced are the reciprocal of E in case (III) and the reciprocal of ET^2/L^2 (As M'_1) in case (IV), which then would change (III) and (IV) to:

$$(E/M) \times 1/L = L^4/T^4 \text{ and } (M'_1/M)/L = L^2/T^2$$

M'_1 would thus dimensionally correspond to M_o in case (II).

The above comparison would show that the basic premises in the conventional gravitational equation are not complete in all respects.

Approach to Conventional Gravitation Equation

According to this theory¹, matter cannot exist without association of energy. There must be some energy association with all Ms in the gravitational equation. Thus the gravitational equation could be written as: $E_1/M_1 L/T^2 = E_2/M_2 \cdot E_3/M_3 \cdot 1/L^2$. If all associations of E with M are dimensionally same, then E_1/M_1 of LHS will cancel, one E/M of the RHS, say E_2/M_2 . The equation would reduce to $E_3/M_3 L = L^2/T^2$. Case (V). This satisfies the dimensional relationship of conven-

tional gravitational equation and is also in agreement with the present theory namely in cases (I) and (II) when E_3 would correspond to M_0 (ET^2/L^2) in case (II), and M_3 as reciprocal property of E_3 . With this stipulation, since $E_3=M_0=ET^2/L^2$, case (V) may be written for fundamental dimension E as

$$E/ML=L^4/T^4 \quad \dots \text{ (Case VI)}$$

(M retaining same significance as for M_3 , but this time as reciprocal of E).

Dimensional representation of gravitational relationship according to the present theory would be as follows:

The force between two momentums of mass at two radial distances from a point source of energy would be equal to difference between energy intensities per square of time at the two positions (radial) multiplied by difference in radial distances.

$$\text{Thus } M_1 \times \frac{L_1/T_1}{L_1} \times M_2 \times \frac{L_2/T_2}{L_2} = \Delta E/T^2 \times \Delta L$$

M being dimensionally equal to ET^2/L^2 , the equation can be written as

$$\begin{aligned} & ET^2/L^2 \times L/T \times 1/L \times ET^2/L^2 \times L/T \times 1/L \\ & = E/T^2 \times L \\ \text{or } & ET^2/L^4 = L/T^2 \\ \text{or } & E/L = L^4/T^4 \end{aligned}$$

The result is the same as that derived from the conventional interpretation of the force equation. The approach in this case, however, it may be emphasised, is entirely different from the conventional approach. E/L is the force between the two. Whereas momentum multiplies per space magnitude, energy intensity multiplies per square of time depending on direction. This should be the fundamental law between the two.

If M would refer to momentum of pure energy (M, which is not dimensionally converted to ET^2/L^2), then momentum of energy developed at a certain orbit

$$(ML)$$

would be represented as $\frac{\text{---}}{T}$. Total energy dis-

tributed at the spherical orbital surface would be $E \times T^2$; at space L, it would be ET^2/L^4 (Space evolution being tetrahedral).

The reaction between these two to establish equilibrium would be represented by $ET^2 \times 1/L^4 = ML/T \times 1/T$ or $(E/M)L = L^4/T^4$ which is the same as was derived in case (I).

Significance of Matter Energy Association

It should be understood that, whenever any situation

of energy and matter combination in the finite universe is considered, neither energy nor matter can exist without the association of the other and their association is fixed according to the state in which they are present in the universal spherical wave. Relative to that state E/M must maintain a constancy. If their relative magnitudes will change, then their positions of equilibrium also will change conforming to the new value in the wave. Anti-matter is energy and anti-energy is matter.

It would, therefore, be clear that due to this either energy or matter in their association relative to a state in the context of the universal spherical wave can be written symbolically as either E/M or $E/1$ or $1/M$. If the magnitude of one is known the other automatically follows. Therefore, in the conventional presentation of gravitational equations where only E appears in the equation, the assumption of the other as reciprocal has to be taken for granted. Presenting the combination by any one of them in an equation, therefore, may not change the basic correctness of significance qualitatively. However, for complete representation of facts in the equation of energy-matter equilibrium manifestation in the spherical wave, all the dimensions associated in the combination should play their part in order to have the significance of various associations realized in the symbolic presentation, conforming to equilibrium configuration in complete perspective.

Conventional Gravitation and Inverse Square Law

The conventional gravitational equation, dimensional presentation of which is in conformity with the basic approaches in conventional interpretation of Inverse Square Law, suffers from the same limitations as would be evident from the conventional definition of the Inverse Square Law. That this is so has been explained in details in Chapter VII of the previous study 'Evolution and Inverse Square Law'² which are as follows:

(a) In the inverse proportionality of force with square of distance, the latter, i.e. "square of distance" does not refer to radius or diameter as is conventionally interpreted. The "square of distance" is merely a space configurational area, referring to the spherical surface developed, with respect to the centre, the origin.

(b) The dimension E, being fundamental, is a fundamental constant in the finite configuration of the evolutionary wave in which only the intensity of E varies in configuration between centre and the boundary as $1/T^2$ (i.e. by association in the spatial configuration with square of time).

(c) π is not an absolute constant as it is conventionally taken to be. It has the dimension T/L (as T/2r) and varies with magnitude of radius as L.

(d) Further, in magnitude π would appear to vary similarly with M or L as opposed to E or T.

(e) Tetrahedral evolution has perfect isotropic significance both in relation to origin and the evolved positions. Association of variability with the generated positions describes spherical surface configuration.

It should be noted that these new aspects are not incorporated in the basic concept of the conventional interpretation of Inverse Square Law which resulted from incomplete understanding of the evolution of a manifestation due to the fundamental dimension of energy and establishment of equilibrium at states of different magnitudes.

Another aspect is incomplete recognition of all the factors which establish equilibrium between opposites and how this equation of equilibrium also conveys significance of configuration of the equilibrium viz., in the equation of equilibrium between opposites (e.g. $+/- = -/+$), sign of equality relative to equality equilibrium spherical surface ABCD. In the left hand side, magnitudes of opposites refer to states towards the centre from the equality equilibrium and in the right hand side these refer to states towards the boundary from the equality equilibrium. In the left hand side, (+) signifies the magnitude of fundamental dimension and (−) sign denotes the magnitude of the dimension containing it. On the right hand side (−) sign denotes the derived opposite of the fundamental and (+) sign signifies the containing dimension of the derived.

It has been shown before that, applying this to the energy matter equilibrium manifestation, we get $ET/ML = \text{a constant}$. If the magnitude of this constant would refer to conditions towards the centre, then that would tend to infinity; at the equality equilibrium, the magnitude of the constant would be unity; towards the boundary, depending on conditions at the boundary, the magnitude of this constant would tend to negative infinity or nil. This conclusion is in conformity with the relationship of modern statistics which has been explained.²

Correct appreciation of Significance of Dimensions

It would be obvious that in order to follow the postulates of the present theory, perspective understanding of the significance of fundamental and derived dimensions is essential. The difference between them in their intensities, potentials or probability must be

understood. Whereas the fundamental dimension can become the cause of an evolution, the derived ones cannot; the former can assume a magnitude of potential of infinity; the derived ones only can be of finite highest. The fundamental could exist in its abstract or fundamental form with infinite potential whereas the derived ones cannot exist in abstract state without the association of the others. It is the infinite magnitude of potential of the fundamental dimension which is responsible for creation i.e. creating finite manifestations by associating with the magnitudes of the derived ones as opposites and generating the configuration of the evolution as spherical wave, wherein the derived dimension occupies its highest at the boundary, and the fundamental occupies the centre at its highest potential. Modern science does not differentiate between the properties of dimensions in this manner. Therefore, the correlationship of equilibrium equations for various manifestations do not also have simultaneously a clear concept of associated configuration. Consequently, these laws do not possess universal applicability correlating the various manifestations in various states of existence by a single unique unified configuration as in the present theory.

Explanations of Some Important Phenomena Unexplained So Far

By applying in proper perspective the configuration of the universal spherical wave with correct dimensional significance and the nature of the magnitude of states of equilibrium equation with the knowledge of the phase characteristics i.e. homogeneous or heterogeneous, it should be possible to know the mechanism of any phenomenon, be it the energy matter evolutionary manifestation as exhibited in progressive evolutionary contexts as quasars, the nebulae, sun or the planets in the solar system; it can be to understand the significance of gravitation (in the form of attraction or repulsion)—not only an apple falling towards the earth, but also a hydrogen bubble at atmospheric pressure flying off from the surface of the earth; or it could be gravitational attraction or repulsion as exhibited in electro-magnetism; (this has been explained in detail)^{1, 2} the phenomenon of semi-conductor allowing current to flow only in one direction or a chemical reaction proceeding in one direction, mechanism of phenomenon of catalytic reactions or equilibrium existence of animal and vegetable kingdoms or thermoelectricity flowing in one direction between junctions etc.; all have significance of gravitation in one way or another. Sudden cooling of a volume of

water vapour in space leading to gravitation of the matter positions in gas phase towards formation of liquid droplets or applying energy in the form of space to liquid droplets to disperse the positions in spatial configuration in vapour phase could be likened to gravitational attraction of the positions towards the formation of droplets in the first case and repulsion of the matter positions from the state of liquid droplets dispersing in space by repulsion to form gas phase in the second.

Catalysis

Just like vacant positions of the imaginary tetrahedral configuration assumed to be associated with the fundamental dimension in its abstract state, when the configuration is associated with finite magnitudes of derived dimension it causes the finite universal manifestation. The position becomes active, acquires variability and exhibits magnitudes of space and time, and its relative intensity causes various universal phenomena. Catalyst also has its configuration, having unfilled positions at its perceptible equilibrium state of existence.

According to this theory, catalyst is a resultant dynamic equilibrium configuration generated due to vibration of a component configuration between two opposite phases, just like the configuration of the universal spherical wave is the resultant between four outer tetrahedrons, face to face, with one central tetrahedron in opposite phases. In fact, for all entities, capable of independent equilibrium existence, there are resultant equilibrium configurations of component configurations vibrating between opposite phases.

In a catalytic chemical reaction, the reactant matter positions in space, as gas having in association with space a certain magnitude of energy intensity, would first be gravitated towards the surface of the catalyst to occupy vacant or unfilled positions of the component configurations in its first phase. The component configuration with these reactant positions filled in from the first phase, while oscillating towards the second phase, orients the reactants in their association to products at the second phase where the conditions would be such that the product positions, having undergone orientation in their constituents in association, would be repelled from their positions in the second phase, having acquired certain associated magnitude of space and energy intensity which is different from that which was in association with reactants in the first phase.

This subject has been dealt with in details separately.*

Ikeya Seki Comet

A satisfactory explanation of the observed phenomenon of the comet, while proceeding towards the sun, getting disintegrated and developing tails, could not be found from the conventional understandings in modern science. But it can be easily explained by applying the principle of spherical wave of the energy field. This has been explained².

Space Magnitudes of Colours

Another phenomenon, which can be verified experimentally, is about the differing of apparent distances observed from point source of different colour positions located at the same point. When two different radiating colour positions, say a position of red light and that of green light, are placed at the same point and are observed from a fixed position in space and time, the red light would appear to be nearer than the green to the observer, the reason being that the two colour positions have different magnitudes of configuration of space for the different colours and the red light, having bigger magnitude of space associated, would thus appear to the observer situated nearer than the green position having smaller magnitude of space configuration associated with it. This aspect has been mentioned in chapter 12 of the author's previous study³, "Energy Field of the Universe and Atom", Part II. This phenomenon will be further explained in a future issue.

Elementary Matter and Periodic System of Elements

The theory explains the significance of various stages in energy to matter transformation. Energy (fundamental) first develops associated matter with energy in one form. The energy next degenerates into dimension ET^2/L^3 which exists in equilibrium in segregated form in field energy space. This matter, by its cumulative effect of distribution in a configuration, forms elementary matter as atomic mass having highest magnitude of momentum and mass (intensity) at the boundary. The present theory gives a clear insight into the synthesis and constitution of matter as elementary matter, and gives a new interpretation to the periodic classification of elements in terms of progressive development of spatial configuration with increase of atomic number and weight and in the periodicity of their configuration. This gives also a new interpretation to the periodic classification of elements, and particularly it throws

* Chakravorty, K. R., Mechanism of Catalytic Chemical Reactions in the Light of the Theory of Universal Spherical Wave, *Technol.*, 3 (1966), 2, S16

an entirely new light on the construction of the first group of elements. Conventionally, the first group of element is considered as 2, hydrogen and helium. According to this theory, the evolution of elementary matter is governed by $(E/M)L=L^2/T^2$. The evolution of elementary matter in the universal field², according to equipotential evolution in the heterogeneous field, has been explained which is applicable to material evolution as elementary matter; the progressive evolution should follow numerical series as $4Z^2$ where Z could be equal to 1, 2, 3, 4, ... etc. in the direction of increasing magnitude of matter (atomic weight, atomic number). The actual series in different groups accordingly would be 4, 16, 36, 64, ... The break-up half would be 2+2, 8+8, 18+18... etc. Each pair forms the equilibrium for a group. Accordingly, the cumulatives starting from least magnitude becomes 2, 4, 12, 38, 56,... This series is different from the conventional series for inert gases where the various groups are 2, 10, 18, 36, 54,... and so on. The classification suggested in the present theory consists of four elements in the first group of 2. The rest of the numerals associated with the other classification remains the same as before. This suggests that in the first pair of elements in the sub-group, it starts first with photon with the least matter significance and ortho-hydrogen. Neutron is the third element and para-hydrogen the fourth. Many of their properties also justify this classification which has been explained². Here ortho- and para-hydrogen are considered as two different elements. The photon and neutron are the first and second inert gases in elementary matter evolution. If this suggestion would be correct, then the two hydrogens—ortho and para—ought to have different atomic weights and numbers, and ortho should have less mass than para; the atomic mass of neutron should be higher than ortho but less than para. Experiments could verify the validity or otherwise of this prediction.

Space and Vacuum

The present theory revives the Ether concept of space—i.e. space is not vacuum. It is neither Ether nor vacuum but space itself is energy, the two having opposite significance of magnitude in association i.e. any equilibrium magnitude of energy and space are opposite (reciprocal). In this finite universe there is nothing which is vacuum. Whatever is conventionally understood to be vacuum is only the space containing energy filtered from matter positions.

Other Aspects

Emphasis on these is made again for correct

understanding of some other important aspects of this theory, such as:

(1) Limitation of physical perception: magnitude of realization by perception of a concept is limited. In this theory, magnitude of the physical perception, by whatever means from a fixed space—time position, cannot be more than half of the total concept.

(2) The significance of dimension of space and time in a common configuration in terms of space magnitude has to be understood as space being radial and time orbital, and also space being four directional and time three directional.

(3) The magnitude of size of container configuration and the magnitude of intensity of contained are opposites in magnitudes. Energy is space intensive and matter is time intensive.

(4) The realization of certainty to uncertainty in magnitudes of various dimensions follows as in (1).

(5) The difference between the mass and momentum of matter.

(6) The intensity and pressure of energy.

(7) The homogeneity and heterogeneity of phases.

(8) Distinguishableness and indistinguishableness of the dimensional entities.

(9) The nature of variability continuous and intermittent—relating to the configuration and constitution of universal spherical wave.

(10) The synthesis of pure energy takes place in space and matter synthesis in time dimension. All these should be clearly appreciated for full understanding of the configuration of the universal spherical wave.

It should be re-emphasized that in order to understand this theory in its proper perspective, the basic postulates and premises must be followed thoroughly. Otherwise, adopting conventional approach and interpretation to the terminology used, which in many cases convey different significance, the theory would appear to be a bunch of confused conjectures, having no logical reasoning or relationship to either perception or conception.

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Mechanism of Catalytic Chemical Reaction in the Light of the Theory of Universal Spherical Wave

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The universal spherical wave of energy matter-space-time equilibrium is a finite configuration as resultant of tetrahedral configuration made up of tetrahedral units. Of these four dimensions, the fundamental dimension, energy, which is the cause of the evolutionary spherical wave, in its purest form i.e. in its infinite magnitude of intensity (abstract state of existence) has no association with any cognisable dimension like space, time or matter. Since energy in its infinite equilibrium state of existence in the universal plane starts assuming regular tetrahedral configuration, the fundamental dimension of energy in its infinite pure state was associated only with an imaginary tetrahedral configuration. It is only when these imaginary positions of the configuration of the fundamental are associated with derived dimension of matter, the universal manifestation and activity starts. In this work, the phenomena of catalysis has been likened to the configuration associated with the fundamental dimension. Catalysts, likewise, in their purest form have certain imaginary configuration associated which, when filled in, is oscillating between two faces during which the associated reactants in the configuration are oriented into the products in the configuration. The starting point of the reactants in the vacant positions in the catalyst configuration and the ejection of the products from the catalyst configuration in the second phase are the process of absorption and desorption involved in the phenomena of catalysis. In this paper, the various sequences of stage of catalytic reaction starting from the reactant in a gas-based product has been described applying the above mechanism.

The essence of the theory of universal spherical wave is as follows: *For every isolated manifestation of evolution there is one fundamental dimension and the other its derived opposite, each associated with its containing dimension. In the spherical wave comprising energy, matter, space and time, energy is the fundamental, matter the derived dimension, while space and time are the containing or configurational dimensions of energy and matter respectively.*

The configuration of spherical wave of the inanimate universe of energy, matter, space and time is a finite, complete concept of equilibrium existence. This concept of configuration is similar to that of an isolated system in thermodynamics in which the contents in the configuration are self-sufficient. The significance of the configuration of isolated equilibrium existence lies in that all dimensions constituting and establishing it are self-sufficient in establishing the equilibrium without the influence of or dependence on any other

external factors or agencies outside the configuration. The contents of the configuration, which establish equilibrium, are energy and matter which exist in equilibrium at various equipotential surface states at which their relative magnitudes of intensities in combination depend on their location in the configuration of the spherical wave between the centre and the boundary. The spatial configuration of the universal spherical wave is constituted by the magnitudes of space and time, and the magnitudes of matter and energy in the spherical wave in terms of their intensities are relative to the magnitude of their (respective) containing configurational dimensions, viz. time for matter and space for energy. Actually, if energy and matter are explained in terms of space and time in the configuration of the spherical wave, then matter would be described as intensity of time and energy as intensity of space.

The configuration of the spherical wave (Fig. 1),

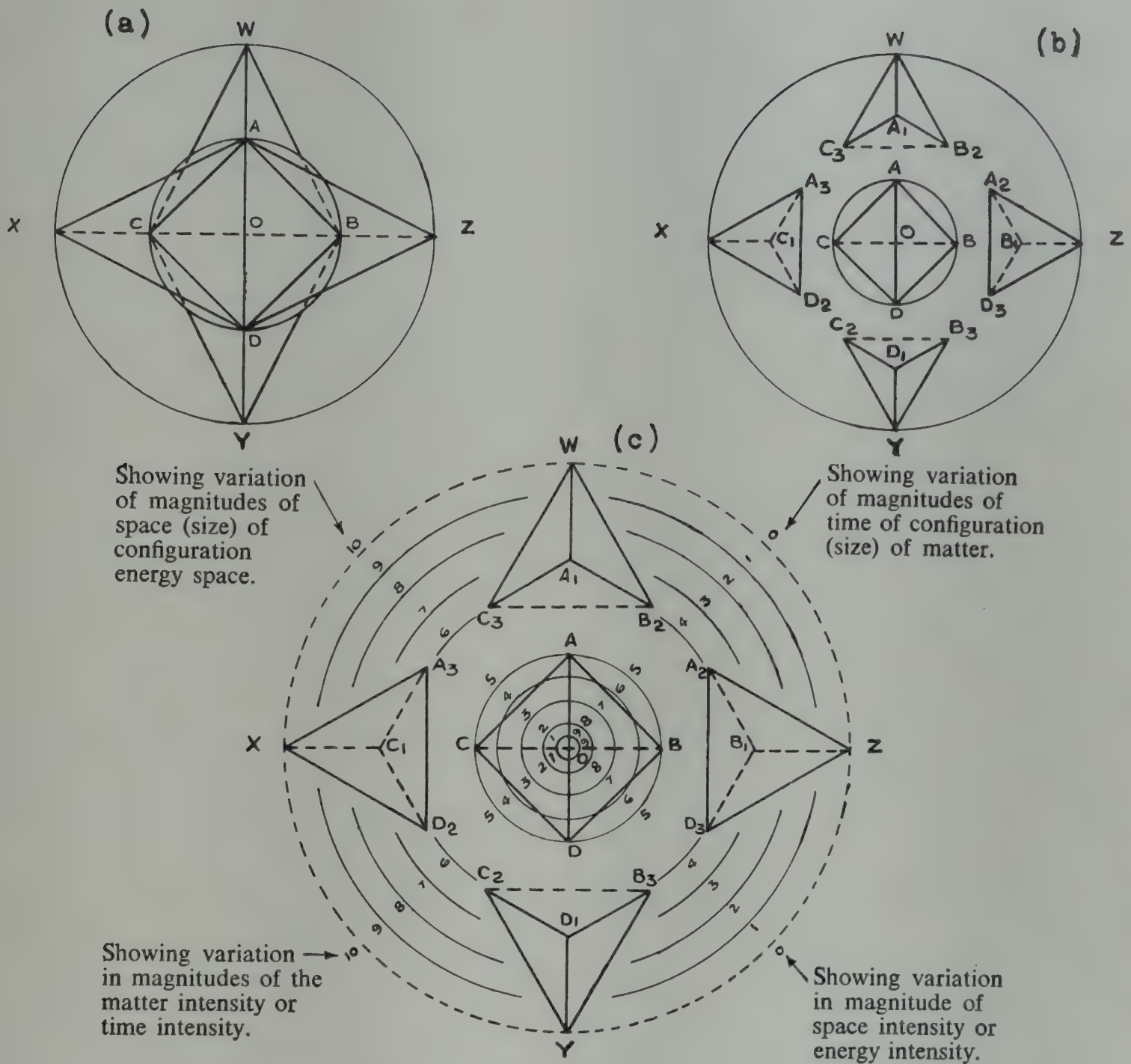


Fig. 1.

Fig. 1(a) represents a central tetrahedron ABCD together with four tetrahedrons placed face to face at the four triangular faces of the central tetrahedron. The central tetrahedron represents the homogeneous phase where the fundamental and derived dimensions exist in one inseparable form. The four outer tetrahedrons, with the intervening empty space, constitute the heterogeneous field of the Universal Spherical Wave, between ABCD and the boundary Spherical Surface passing through the apex positions W, X, Y and Z of the four tetrahedrons.

In Fig. 1(b) the same configuration in Fig. 1(a) has been shown by separating the four outer tetrahedrons from the inner one.

In Fig. 1(c) the same Universal Spherical Wave is shown, for clearer understanding by incorporating the spherical surfaces in between the centre and the boundary, four in the homogeneous and four in the heterogeneous zones.

arises from two significances of magnitudes of containing dimensions, viz. intensity and size of the dimensions. The space-time configuration of the spherical wave had the intensity of fundamental maximum at the centre and that of derived least; the magnitudes of size of the containing dimension of the fundamental and the derived at the centre are the lowest and highest, while their intensities are the highest and least respectively. The centre is the position of least variability of the fundamental and derived dimensions. The boundary spherical surface of the spherical wave is so constituted that the distribution of fundamental dimension-energy at the spherical surface leads to the least intensity, whereas the converging matter positions have the highest magnitude of intensity. The configurational magnitude of time relative to matter the boundary is least but its intensity is at highest.

Actually, energy and matter, in the spherical wave configuration, are the intensities of space and time respectively. These may be called force of space and time or activity of space and time and so on. The universal spherical wave exists with these containing dimensions at the centre and the boundary and their variation is between the centre and the boundary; at one particular spherical surface, their magnitudes are equal. This is the equality equilibrium surface. At the centre, the variabilities of energy associated with matter as one indistinguishable whole are least; but as the configuration expands, these go on increasing till their highest value is reached at the equality equilibrium surface. At the boundary, on the other hand, matter and energy exist as two separates with least variability associated which again increase towards the equality equilibrium surface where it is highest. Thus, the variabilities of energy and matter increase in opposite directions, one from the centre and the other from the boundary but from both states towards equality equilibrium surface where their magnitudes increase till they are highest at the equilibrium surface in the configuration of the spherical wave. The spherical wave is thus a cumulative configurational concept of states of equilibrium existence due to a fundamental dimension and its derived opposite, associated with their respective containing opposite dimensions. The equilibrium configuration can be described as the equilibrium of two opposite pairs of two opposites. Energy, matter, space and time in this equilibrium configuration can be expressed as:

$$ET/ML = \text{Some constant of equilibrium.}$$

The magnitude of the equilibrium constants can vary between infinity and nil and these values would correspond to the equilibrium states at the appropriate spherical surfaces in the spherical wave in accordance with their intensity or potential gradients. According to this theory, evolution is tetrahedral, i.e. fundamental, while starting the evolution, first creates with its highest intensity at the centre, four positions of derived opposites of least intensity which subsequently undergo expansion, and which in the context of the entire spherical wave can be conceived as five tetrahedrons; the one between the centre and the evolved equality equilibrium surface is situated in a homogeneous region where matter and energy remain as one inseparable, while the other four tetrahedral configurations are situated in the field between equality equilibrium spherical surface and the boundary of the wave. Each of the latter tetrahedrons corresponds to a matter configuration converging to one of the four positions of the highest matter intensity at the boundary. At the boundary, the matter and energy are segregated; the tetrahedron occupies the matter dimension and the remaining space is associated with energy. This is the heterogeneous zone of the universal spherical wave where matter has segregated out from energy space and each configuration of matter is in association with space of certain energy potential. If the matter configuration is nearer to the equality equilibrium, the magnitude of configuration of space and energy is less but in association with higher intensity of space and energy. The relative magnitudes of intensities of matter configuration to energy in space configuration in the heterogeneous field lead towards the boundary with the highest intensity of matter in association with space of the least intensity of energy. The space-time configuration of the spherical wave as such has $L/T = \text{nil}$ at the centre in terms of their configurational magnitude. If their intensity is considered, it would be infinity. If the configurational space and time of energy and matter respectively are considered at the boundary, L/T would be infinity; but in terms of intensity it would tend to nil. The configuration starts with the least configurational magnitude of L/T at the centre and its least intensity at the boundary. At the equality equilibrium space, time intensities as well as their configurational magnitudes equalize. The tetrahedral evolution during radial expansion of energy up to the equality equilibrium covered by homogeneous phase is four directional (conventionally four-dimensional) and the time, which is orbital, is three-directional measured along evolved spherical surfaces. For further details,

references* may be consulted.

Matter in any Form—Gas, Liquid or Solid—must have Energy Associated in the Form of Space

In the finite universe all the dimensions must possess finite magnitudes; and, whatever may be the state of existence in-between the centre and the boundary, all dimensions must be associated in combinations in the manifestation depending on the state of their existence in the spherical wave. The existence of matter, without association of energy-space, is not permissible. The fundamental dimension can only exist in a state isolated beyond the configuration of the spherical wave where it would have infinite intensity which would be beyond any finite conception. Whenever we talk of some matter, like gas, liquid or solid, each unit in its own configuration is associated with some space of certain magnitude having certain energy intensity. Normally, from the relationship in the spherical wave, it would be realized that the higher the associated matter intensity in its configuration, the bigger the magnitude of space having less energy intensity associated; the higher the matter intensity of its configuration, the less the associated space and the more the energy intensity. These basic principles must be fully taken into consideration, where they are applied to chemical reactions.

(Gas is segregated matter positions distributed in space of certain energy intensity). The direction of the magnitude of associated space intensity is opposite to that of intensity of matter in the combination represented by E/M. Therefore, these criteria would govern the nature of transformation from one state of E/M to another, where the transformation would be associated with absorption or evolution of energy, viz. endothermic or exothermic.

Configuration of Universal Spherical Wave vs Catalyst Configuration

It may be recalled that the fundamental dimension in its infinitely purest state of existence is unassociated with any other dimension. But when it causes finite manifestation, it does so by associating with it finite magnitudes of other dimensions forming a regular

tetrahedral configuration in the manifestation. The significance is that the fundamental dimension in its infinite and purest state of existence does not associate with any other dimension but it can only be conceived of possessing an imaginary tetrahedral configuration of nil magnitude position, which would be available for other dimensions to be associated and be active during evolution of finite manifestation. The cause and mechanism of catalytic reaction also should be probed into in this light.

Every manifestation must have an equilibrium configuration. The universal spherical wave as depicted in Fig. 1 in terms of tetrahedral configuration has an equilibrium configuration in which one central tetrahedron is in equilibrium with four outer ones placed face to face with those of the central one. All variations of properties of dimensions constituting the wave follow according to this equilibrium configuration of the universal spherical wave. Although in Fig. 1 the simplest equilibrium configuration has been depicted, this could assume a complicated picture by associating more tetrahedral configurations with the twelve triangular faces of the four outer tetrahedrons which would make the total configuration comprising sixteen tetrahedrons in the outer zone, vis-a-vis one at the centre. There would be a total number of corner positions of 28 (7×4) in the outer zone. The skeleton configuration (Fig. 1) does not show the extra twelve tetrahedrons in the outer zone meaning thereby that the remaining empty space positions in that zone remain unoccupied.

A catalyst also must have its own configuration on its surface. The equilibrium configuration has a crystal-line structure realizable in perception through some apparatus which may not be complete and fully describable by any observed configuration. Only that portion of the equilibrium configuration is perceived in which the filled-up positions are amenable to perception while those not occupied, unfilled or unsaturated are not perceived. These latter do not show up in perceptible configuration. For example, a tetrahedron having its centroid positions fixed may vibrate between two opposite phases ABCD and abcd where 8 total positions having 8 corners of a cube are created and could be perceived as a cube (Fig. 2).

Such a cubic crystal of equilibrium configuration, of course, does not have any vacant positions of the tetrahedrons, while vibrating between the two states. All positions are filled or saturated.

All crystals, however, need not have all the positions in the resulting equilibrium configuration filled to convey

*Chakravorty, K. R., Energy Field of the Universe and Atom, Part I, *Technol.*, (1964), 3, Spl. Issue; Energy Field of the Universe and Atom, Part II—the Theory of Universal Spherical Wave and Modern Science, *ibid*, 2 (1965), 4, Spl. Issue; Energy Field of the Universe and Atom, Part III—the Theory of Universal Spherical Wave and Science in Ancient India, *ibid*, 2 (1965), 4, Spl. Issue.

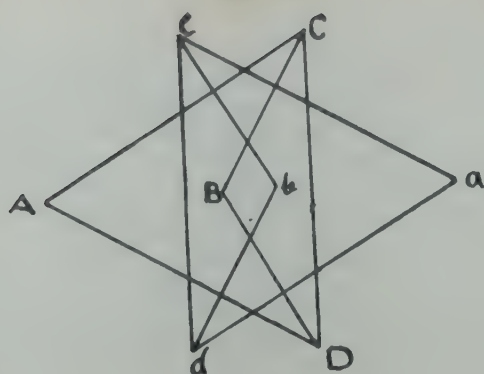


Fig. 2.

a complete picture of the whole. There may be unoccupied positions associated which are not shown up in perception but they exist and can be filled by other matter if those could fit in.

Thus, a tetrahedron, in which one position is not filled, varying between two opposite states, will result in perception as a triangular prism, instead of as a cube (Fig. 3) having six corner positions. In this, however, two positions are unoccupied or unsaturated, which, if filled, would make the configuration appear as a cube.

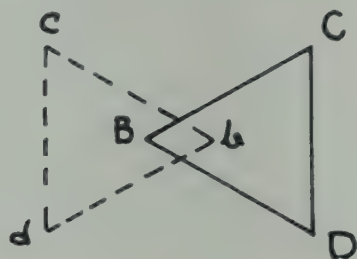


Fig. 3.

All observed configurations should be resolvable into opposites making one resultant equilibrium configuration in perception. The tetrahedron itself is resolvable between two opposite states in pairs of two opposites with respect to a common centre.

The above mechanism would indicate that a catalyst should be one in which there exists an equilibrium crystalline configuration where all positions are not incorporated in the apparent configuration, but some positions remain unoccupied or unassociated or unfilled rendering the configuration incomplete. It is in these vacant positions that compounds as reactants can be adsorbed or chemisorbed and then, due to oscillation of these positions between two opposite phases, they are oriented and transformed into products from the adsorbed reactants. This, as stated before, implies that the apparent crystalline forms observed in the catalyst would be different when the unfilled positions in the configuration are occupied

by adsorbed entities giving the true configuration with all positions filled.

The equilibrium catalyst configuration may be established from one configuration vibrating between two opposite phases (like a regular tetrahedron vibrating between two opposite phases with its centre fixed giving the resultant configuration of a cube) or between two configurations (crystalline forms) of which one adsorbs the reactants and the other receives the same in oriented form as product and ejects them from the system. The presence of a second or third compound mixed in the catalyst also can have an effect in modifying the equilibrium configuration between two states. They may help in generation of more vacant positions in one state or both, or they may start filling up the vacant positions themselves in the two states. Those compounds may act in two opposite ways; they may function as promoters in one and as a poison in the other to the equilibrium catalyst configuration.

It should be noted that the equilibrium perceptible configuration of a catalyst need not be simple or elementary in nature like a tetrahedron oscillating between two states giving the impression of a cube. It can be a combination of a number of associated configurations oscillating between two states. Instead of some vacant positions, these could be some vacant surfaces or some vacant three-directional configuration of positions, taking part in generating equilibrium configuration.

The functioning of the above mechanism of catalyst equilibrium configuration can be illustrated by citing an analogous situation as exists in the living world comprising plant and animal kingdoms on the surface of earth. As has been already explained, the equilibrium catalyst configuration is established between two functionally opposite phases, i.e. the equilibrium configuration has two components of opposite aspects. In the living world on earth's surface, the plant and animal lives are the two opposite components and the two together function as the equilibrium configuration which maintains oxygen-carbon dioxide equilibrium in the earth's atmosphere. Both plant and animal lives feed upon assimilable carbonaceous products but plants by virtue of their functional peculiarities absorb energy and with the help of chlorophyll assimilate carbon dioxide in available form and liberate oxygen during the process. The animal life, however, generally behaves in opposite manner. They liberate energy (due to oxidising reaction within the system) as well as carbon dioxide and absorb oxygen.

Thus, the fixation of energy and carbon dioxide and their subsequent release and utilization with the accompanied exchange of carbon dioxide-oxygen are the two most fundamental opposite properties exhibited by the living entities, namely plant and animal. These functions are analogous to the two opposite phases of an equilibrium catalyst configuration and are responsible for maintaining the equilibrium balance of the concentration of carbon dioxide and oxygen in the earth's atmosphere. These two opposite properties in establishing living equilibrium are the root causes of biological evolution leading to this development as functions have tended to separate or differentiated forms as plant and animal configurations. The detailed analysis of the evolutionary sequence has been presented in a separate article.

If in the earth's atmosphere, by any means, the contents of carbon dioxide and oxygen would not be supplemented to maintain a constant value and the animal kingdom is relatively and progressively eliminated, then the atmosphere theoretically would have increased in its oxygen content and carbon dioxide would progressively tend to get depleted. If, on the other hand, the vegetable kingdom would be progressively eliminated and the animal kingdom would increase, the proportion of oxygen would deplete and that of carbon dioxide increase. In these two cases, the chemical reaction would proceed in one but opposite direction. If this system would have to maintain an equilibrium, then the relative proportion of the abundance concentration of these two states of configuration has to continue to exist for maintaining the equilibrium.

The rate of transformation would depend on the presence of relative magnitudes of concentration of the two entities on the surface of the earth, for reaction towards either direction. If an increase of oxygen and decrease of carbon dioxide concentration in the atmosphere is intended, the equilibrium concentration configurations of the two must be disturbed. In the complete absence of one, say animal, theoretically, the reaction towards increase or decrease of oxygen would be unidirectional. If the other configuration, viz., vegetation, is eliminated, the reaction would be in the opposite direction only i.e. towards increase of carbon dioxide in the atmosphere.

The function of the two opposing configurations of the two states on the catalyst surface is similar to what has been described above. The effects of poison and promoters on decreased/increased activity of a catalyst and its efficiency etc., and the factors that would control them can also be guessed, by interpreting the effect

on transformation on the earth's surface.

Exothermic and Endothermic Transformations

It has been mentioned before that in the spherical wave of energy matter field, space associated with matter has less energy intensity if matter intensity is higher and vice versa. To appreciate this, take the example of hydrogen and carbon dioxide. Hydrogen is less matter-intensive while carbon dioxide is more. According to the theory, the associated space with carbon dioxide would be less energy-intensive than the associated space of hydrogen.

The comparison would be similar to what has been described** as the associated magnitude of space for red colour which has higher magnitude than those of green or blue; when two radiating sources of identical size, for example red and green, are placed on the same spot, it would appear in perception from a fixed position at a distance that the red position is nearer than the green to the observer. This would mean that the shift of the red source from the actual position from any direction would lie at a greater radial distance from the actual position than of green whose observed radial distance is less. Carbon dioxide would behave like the red colour. It is matter intensive, associated with space of less energy intensity or, relatively, unit matter of carbon dioxide is associated with higher space magnitude and less energy intensity. The hydrogen would behave like the green colour such that the unit matter of hydrogen is associated with space of higher energy intensity.

It may thus be realized that when unit matter associated with space of certain energy intensity is converted into another unit matter associated with space of higher energy intensity, the reaction would be associated with absorption of energy, i.e. transformation would be endothermic. In the reverse case, when a unit matter, associated with space of higher energy intensity, is transformed into matter associated with space of lower energy intensity, the process would be exothermic. In the former case, the magnitude of space for unit mass is associated with reduced configurational space and in the latter, the transformation is associated with expanded space.

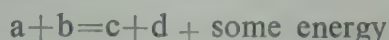
Equilibrium at the Catalyst Surface

Let us now come back to the equilibrium configur-

** Introduction to Understanding of the Theory of Universal Spherical Wave of the "Energy Field of the Universe and Atom", *Technol.*, 3 (1966), 2, S1

ation at the surface of the catalyst. Suppose the configuration between the two states are of equal magnitude. The unit matter positions associated with space of a certain energy intensity are adsorbed in the first configuration but are transformed into a unit matter of the same intensity as before, and its configuration also retains the same magnitude with associated intensity of space also the same. Therefore, there is no change in either matter or associated energy characteristics between the two states. The change is isothermal. If the first configuration adsorbs unit matter position with associated space of certain energy intensity after transformation to the second phase and if the associated space would be of a higher intensity, the matter position formed should have less matter intensity. However, at the second state, the matter position must have increased intensity and the associated space will have less energy intensity. In the former case, reaction or transformation is endothermic while in the latter it is exothermic.

The significance of these may not be realized in the conventional presentation of chemical reactions with the usual atomic and molecular weights and the corresponding gram molecular weights and volumes. Gram molecular volumes of elements are assumed to be constant which presumes that the relative atomic configuration of all elements with their matter content would occupy the same space volume. The present theory, however, demands that the associated space volumes for unit matter are not identical for all. Heavier elements have less energy intensity of space associated with them than the lighter ones. A chemical equation is conventionally presented as:



In the present case the equation would be interpreted as $a+b$ as reactants and the sum of their relative masses remaining the same as that of the sum of products $c+d$, without any mass change between the two states. This brings in the question whether the sum of relative weights of the reactants in the first state, where they existed in space of certain intensity, can retain the same sum of relative weights of products in association with a space of different intensity. In the theory of the universal spherical wave, however, it would be clear that, at the higher space (energy) intensive states, matter exists with less relative weight than its relative weight in less energy intensive space. The relative magnitude of difference, between the magnitude of intensity of the reactant matter positions and product matter positions, may be too small to be discernible through our technical devices. But the fact remains that in any

reaction, when a change from one state to another occurs, if the associated intensity of space changes, the relative magnitude of intensity (signified by relative weight in the present case) of matter also must change. Dimensionally, this has been explained by

$$(E/M) L=L^2/T^2,$$

when E/L i.e. energy intensity of space changes, M also must change, whether applied to transformation of matter to energy in case of electron to photon or change from combination of one group of matter positions to another combination of matter positions.

In the context of the present discussions, however, the above may not stand in the way of understanding of the mechanism of catalytic chemical reaction. But on fundamental considerations, this would require to be reckoned with. Here the conventional practice of retaining the relative matter magnitudes as constants in a chemical reaction has been assumed. An exothermic catalytic reaction would be one in which one or more reactants matter positions combined in space, undergo transformation to a product state when the resultant magnitude of space per unit matter position in combination is higher in energy intensity than the former. When the resultant magnitude of space per unit matter position in combination is lower in energy intensity, the catalytic reaction would be exothermic.

As an example, suppose there is an equilibrium configuration between two phases—liquid in equilibrium with vapour. The liquid, in its configuration on one side has only a few occupied positions, most of them being empty. On the gaseous side, however, the configuration would have most of its positions filled and have space of certain energy intensity which was absent in the initial configuration of the liquid in which there were empty positions. The transformation would be endothermic from liquid to vapour phase and exothermic from vapour to liquid phase.

Catalytic Chemical Reaction Requires Support

Apparently, for chemical reactions to take place, some support is required. In the energy field of the universe, the fundamental dimension—energy—creates its own support at the centre, having four-directional probabilities towards associated derived dimensions; whereas the matter positions have three-directional probabilities towards the fundamental. Chemical reactions in the heterogeneous field, involving solid, liquid and gas entities, also require some support for the equilibrium configuration, through which the reaction can take place in one or other directions.

The phenomenon of heterogeneous catalytic reactions in gas phase is one in which the equilibrium configuration finds its support on the surface of the catalyst. As mentioned before, the equilibrium configuration oscillates between two states or phases. It may be the resultant of one varying between two opposite phases in one uniform or pure catalyst support only i.e. one chemical compound only. The resulting configuration may be due to two or more different crystalline forms of the same compound or may be the resultant effect of two or more different chemical compounds. One configuration or one compound may be suitable for drawing the reactant matter positions as gases with associated energy intensity in one direction only, but only half-way through towards completion of the reaction to products.

The function of the configuration in the second state is to complete the reaction, orienting the reactants to combinations of the matter positions as products. The function of the promoters would be to provide the configuration of the second phase or the first state carrying only half of the reactants or the main catalyst may possess both the configurations. In this case the promoters may serve the purpose of providing their own equilibrium configuration for preferentially accommodating certain matter positions which could, by settling down in the main configuration, reduce the activity of the main equilibrium configuration. The effectiveness of the catalyst would depend on the functioning of the associated vacant positions in the oscillating configuration between the two states. The activity or efficiency of the configuration could be reduced due to the existence of other matter positions besides reactants to permanently occupy the unfilled positions. Poisons could reduce the effectiveness of the catalyst by functioning in this manner.

Sequences in the Mechanism of Catalytic Chemical Reaction

The occurrence of a chemical reaction on the surface of a catalyst requires the following sequences:

(a) The reactant phases, defined as positions of atoms of matter distributed in space of certain energy intensity, must first of all require to be drawn towards the catalyst surface to occupy available positions in the catalyst configuration conforming to the *first state*. This action requires the matter positions to be drawn closer to each other either by a natural attraction to fill the unfilled positions in the catalyst configuration in the *first state* or the reactant gas positions may require to be concentrated by application of pressure.

The first case is one which can take place at normal atmospheric pressure conditions. The second case can take place only under higher pressure. The first action in the catalytic transformation of the reactants to products would be their transition from the initial existence of the reactant matter positions in space as gas to find their accommodation on the surface of the catalyst filling the available unoccupied positions in the *first state* of the catalyst configuration. The process can be accomplished under atmospheric conditions as well as at a higher pressure, depending on the magnitude of natural attraction of the reactants towards the vacant positions. A higher pressure application would be required in a case where natural attraction is less. This is one way of expressing the action of adsorption of reactants on the catalyst surface.

(b) The second step is the change of orientation of the catalyst configuration in the first state, with reactant positions occupying the unfilled positions, to the catalyst configuration in the *second state* in which the reactants have been converted into products, i.e. the reactants have undergone orientation in their combination. During this process the reactants, which were present in the *first state* of the configuration associated with certain intensity of space energy, have also undergone change in the *second state* in which the products in the configuration associate with changed energy intensity of the space as well as magnitude of size of configuration. This would make the reaction either exothermic or endothermic, as described previously.

(c) The third step in the process is the ejection of the product matter positions from the *second state* configuration into the product gas phase outside catalyst.

The rate would be determined by the presence of the difference in the concentration of the product positions surrounding the catalyst, which again will be dependent on whether the product undergoes natural repulsion from the configuration or would require some other agency to eject it from the configuration. If the product matter positions in space are continuously removed from the surface of the catalyst and reactant positions continuously supplied, the reaction would be unidirectional under dynamic flow conditions.

Phenomena of Adsorption and Desorption

Before a detailed examination of the sequence in the mechanism of catalytic reaction at the surface is made, it is necessary to make the approach clear in the light of the theory of spherical wave about the significance of the initial and final steps in the process between

which the mechanism of catalytic reaction occurs. The initial step is the act of drawing the reactant positions towards the surface to settle on it, i.e. the phenomenon of adsorption. The final step of the catalytic reaction is the ejection of the product from the surface of the catalyst which is desorption.

Adsorption in this case would be similar to the gravitation of matter positions drawing towards one. The reactant positions can be drawn to fit into the vacant positions in the catalyst configuration by two means. In the first method, the size of orbit (i.e. magnitude of orbit or configuration) in its own configuration is to be brought to a magnitude which would be naturally attracted to the orbit of the vacant positions of the catalyst configuration which they would occupy. The other way is to make the reactant positions distributed in space to be brought to correct concentration to suit distribution in the catalyst configuration in the *first state*. In this way, the reactants can be adsorbed on the surface of the catalyst and settle in its configuration forming the *first state* or *state* of equilibrium catalyst configuration. The process involves either increase or decrease of the orbits of reactant positions to fit in the orbit of the positions in the catalyst configuration; the second is by the increase of pressure increasing the concentration of the reactant positions to fit into the catalyst configuration in its first phase.

The mechanism of desorption would similarly follow two ways. The product positions formed in the *second phase* of the catalyst configuration may possess natural orbit bigger than that of the catalyst configuration due to which the positions could fly off from the configuration. The second would be such that the intensity of the product positions becomes higher in the configuration than the surrounding gas phase, when the

product positions automatically would be ejected from the catalyst surface towards gas phase.

It follows from the above that, if the absorbed reactants possess a configuration smaller than that of the catalyst and the corresponding product-configuration is bigger, the reactants would be adsorbed and the products would be ejected from the catalyst. Alternatively, if the concentration of the reactants is higher than that of the position in the catalyst configuration in the first phase and the product concentration in the catalyst configuration in the second phase higher than that existing in the gas phase outside the catalyst, the reactants would be adsorbed and the product would undergo desorption.

Mechanism of Reaction

We would now revert to discuss the mechanism of catalytic reaction at the surface and the various sequences involved in the process of catalytic reaction, starting with the reactant phase during the first state of catalytic equilibrium through the second state of catalytic equilibrium to the product gas phase. These four steps in sequence are shown below:

The reactant matter positions in gas phase is state No. 1 (Fig. 4); reactant adsorbed in the *first phase* of the equilibrium catalyst configuration forms state No. 2; the state No. 3 is the *second phase* of equilibrium configuration with the product positions formed; state No. 4 is the product position in the gas phase. It has been assumed that the equilibrium catalyst configuration is constituted of tetrahedron with fixed centroid vibrating between two opposite phases with only one position filled (configuration with 8 positions would be cube) and, three positions, i.e. positions making a triangular

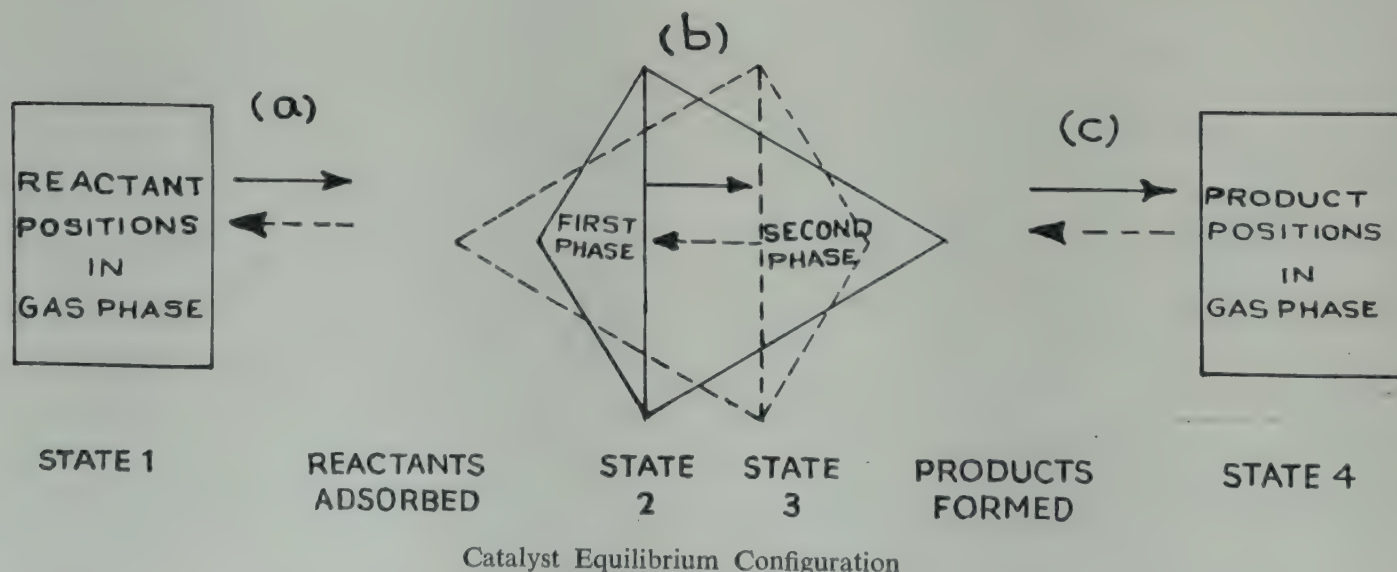


Fig. 4.

face vacant (Fig. 4). There are three steps of activity in sequence in one direction:

First action (a) is conversion of the reactant positions in gas phase to positions adsorbed in the *first phase* of the catalyst configuration. Second action (b) is vibration of the tetrahedron with the vacant positions between the *first* and *second phases* during which the adsorbed reactants are reoriented in their combination to form product positions occupying the positions in the second phase of the configuration. The third action (c) is the desorption of the product positions from the catalyst configuration to the product positions in the gas phase outside the catalyst.

Rate of Reaction

Thus, all the three steps or actions are factors controlling the reaction. The first controlling factor for progress of reaction, i.e. rate of reaction in one direction depends on the rate at which the two phases of the equilibrium configuration change from one phase to the other, i.e. the frequency of vibration of the configuration between the two phases. Thus the rate in forward direction, assuming maximum frequency at (b) and complete removal of product positions from the surface and sufficient reactant positions available at (1) and the least product available at (4), would be maximum. For the reverse reaction, the opposite conditions at the various steps would be necessary. One of the important effects of temperature is to increase the frequency of vibration of the component configurations in the catalyst action at (b).

The second controlling factor is action (a). Assuming that frequency at action (b) is maximum, the availability of reactants positions and their concentration in the reactant gas phase should be such as to provide the necessary driving force to maintain the rate demanded by the presence of vacant positions at state (2) at any instant. The orbits of the reactant positions in their configuration and their concentration would be required to suit this condition. The removal of the product position from state (3) would depend on the concentration of the product positions in the configuration in its second phase vis-a-vis their concentration in the product gas phase as well as the difference in size of configuration of the products, vis-a-vis the size of catalyst configuration in its second phase of the present theory. It is clear that the rate of forward action (a) would depend on the difference in time magnitude of configuration (size) between (1) and (2) and difference of concentration (intensity) between (1) and (2). The less the magnitude of size

at (1) and the higher the intensity or concentration, the greater would be the forward rate. Between (3) and (4), the forward rate would depend on the difference of product concentration between states (3) and (4) and the magnitude of configuration of the product positions being greater than that of the second phase. The higher the concentration and the smaller the size at (3) relative to (4), the greater would be the forward rate.

Equilibrium Conversion and Concept of Space Velocity

The equilibrium, it would be foreseen, would depend on the resultant between the forward rate and the reverse rate which would ultimately depend on the frequency of action at (b) on the one hand and the actions at (a) and (c) on the other, depending again on the concentration of reactant and product positions in the gas phase. If there is no supply of reactant and no withdrawal of product, the rate of forward conversion is nil. If there would be supply of reactants and no withdrawal of products, the rate of forward conversion is nil. If there would be supply of reactants and removal of products, then only there can be actions (a), (b) and (c) in the forward direction. Conditions are reversed for the reverse reaction. The concept of space velocity would now control the equilibrium conversion. Suppose that the supply of number of reactants positions in space at any instant is less than the available vacant positions at (2) at any instant and products are removed the ratio of the number of product positions to reactant positions will give a conversion ratio greater than unity. In another case, the number of reactant positions may be equal to the vacant number available at state (2) so that the ratio becomes equal to unity. The next case would be the supply of number of reactant positions higher than available at any instant at state (2); then the ratio of the product positions to reactant would be less than unity. In the second case it was unity, and in the first case it was greater than unity. For a certain frequency of vibration of the catalyst configuration, i.e. at a certain temperature of the catalyst, for a definite number of configuration, i.e. for a given volume of catalyst, the rate of supply of reactant gas has a profound effect on the conversion ratio of the product position to reactant gas positions, i.e. equilibrium conversion in a dynamic flow condition. This phenomenon is the so-called effect of space velocity on the equilibrium condition in a catalytic reaction. At low space velocity, percentage conversion is higher than that at the higher space velocity.

Functions of Promoters and Poisons

From the above illustrative example covering four states (1), (2), (3) and (4) it will be clear that promoters and poisons are relative terms. What is a promoter for the forward reaction is a poison for the reverse reaction and vice versa. The probable functions of promoters for, say, a forward reaction to take place, would be one which (i) could increase the frequency of action (b); (ii) could be also to assist ejection of the products; (iii) could be to resist or block the action at (b) in the reverse direction. The last action can be similar to that in a rectifier converting alternating current to direct current. It is also similar to the case in which a configuration can vibrate in two opposite directions but in which, when a foreign influence stops vibration in one direction, unidirectional pulsating motion results. This can, thus, modify the vibration; (iv) can also be to allow foreign matter positions to be preferentially adsorbed and settled on it rather than allowing them to occupy the vacant (active) positions in the catalyst configuration.

Semi-conductors

A suggestion for the mechanism of functioning of semi-conductors can be described in a similar manner as the mechanism of catalytic chemical reaction. The semi-conductors also have equilibrium configuration of positions in which the positions oscillate between two phases and produce the overall configuration in dynamic equilibrium. Like the catalyst configuration the positions of a semi-conductor, in its first phase, may accept electrons of higher intensity and convert them in the second phase at lower intensity. Other semi-conductors can be of opposite nature, i.e. positions in their configuration in one phase will only accept electrons of lower intensity and convert them into electrons of higher intensity.

The positions of semi-conductor configuration in its pure state is inactive and static, the material in that state is inactive as semi-conductor. This is similar to the state of fundamental dimension energy, in its purest state of infinite intensity with its associated imaginary tetrahedral configuration in its abstract state of existence which is the cause for subsequent occurrence of manifestation of energy-matter universal spherical wave. For catalyst material prior to the state when it is functionally active as catalyst or the semi-conductor configuration prior to the state when it is functionally active, the configurations of these materials existed as the cause of their subsequent functioning. At that state their positions in equilibrium configurations

were vacant or unoccupied by any thing or for all intents and purposes the configurations at that state can as well be called imaginary. It is only when the positions of their respective configurations accept the reactants as in a chemical reaction or relevant agents in a semi-conductor, their respective functional characteristics become operative.

Thus the activity of the semi-conductor will only start, just like the activity of the catalyst starts, when the reactants occupy positions in the first phase of oscillation of its configuration. When the configuration of the semi-conductor in its vacant positions in the first phase receives electrons, its dynamic activity starts vibrating between two opposite phases. This creates possibilities of two kinds of semi-conductors, each of opposite characteristics. The specificity of a particular semi-conductor would lie in the fact that if the positions in its first phase will entertain electron only say at higher intensity, in the second phase those would be converted to lower intensity.

The other kind would be a semi-conductor whose configuration would only allow it to accept electrons at lower intensity in the first phase and convert it to the second phase where the electrons will be in higher intensive state.

If the two types of semi-conductor materials are brought in contact, one of the semi-conductors can receive electrons from a negatively charged conductor in its first phase of configuration at higher intensity and convert into low intensity in its second phase. From the contact point between the two semi-conductors the first phase of the second semi-conductor configuration will accept low intensity electrons and convert them into electrons of higher intensity in its second phase from which the electrons can be removed by a positively charged conductor. Two semi-conductors thus arranged would function as a rectifier allowing passage of unidirectional electron flow.

Electron at higher intensity and lower intensity could also be associated with factors, say higher electrical potential in one phase and higher thermal potential in the other phase respectively. There could be two possible cases. In the first case a single semi-conductor would receive electrons in the first phase and would have the tendency of liberating in the form of heat energy in the second phase. In the second case the tendency of the semi-conductor would be to receive or absorb heat energy in the first phase and convert into electrical energy in the second phase. The former would have exothermic tendency and the latter endo-

thermic; likewise the former could be deficient in electron concentration and the latter with excess of electron concentration.

Ion-exchange Resin

Before concluding it may not be out of place to mention a similar phenomenon like that of catalysis as is observed in ion-exchange resins. The ion-exchange resin should also have some equilibrium configuration of its own like that of catalyst. The unfilled positions of the resin configuration can attract either cations or anions depending on the nature of configuration of the resins. Like the catalyst the configuration of the resins should also be specific for either cation or anion. The exchange characteristics would depend on the cationic or anionic potentials of the ions to be adsorbed and the concentration of ions present in the supernatant fluid. The mechanism of catalysis however is different from the mechanism of ion-exchange. In the mechanism of catalysis, catalytic configuration after adsorbing the reactants in the unfilled positions of its configuration orients the reactants to products by oscillating between two phases, viz. the reactant

and the product phases. The catalyst configuration is dynamic. As against this, the configuration of the ion-exchange resin is static. It does not oscillate between initial and final phases like vibrating catalyst configuration between two phases. The resin configuration being static, in the ion-exchange where number of positions are unfilled or unexchanged, ions from supernatant fluid will get exchanged either by virtue of their concentration in the fluid or by virtue of their ionic potential. The process of exchange should continue till all the available positions in the resin configuration are filled or exchanged by the ions. The resin positions will require to be treated to regenerate their ion exchange activity.

Comparing mechanisms in the 3 cases, viz. catalysts, ion exchange resins and the semi-conductors, the following would emerge: The catalysts and semi-conductors manifest similarity of their specific activities of equilibrium configuration vibrating between 2 phases by which each maintains continuity of reaction flowing in one direction, whereas in the case of ion-exchange resin its configuration seems to be static as the exchange reaction is intermittent.

Evolution of Plant and Animal Life in the Light of the Theory of Universal Spherical Wave

Concept of Food and Nutrient

By

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Conventionally, fertilizer is termed both as plant food and plant nutrient. However, the words 'Food' and 'Nutrient' do not connote identical meaning. 'Nutrient' signifies contribution towards 'vitality', whereas 'Food' towards 'growth and sustenance'. While the former could be the cause, the latter may be the effect. Thus an important question to be answered is whether fertilizer is to be treated as 'Nutrient' or 'Food', particularly in today's world context, because, if one of the meanings alone would signify the role of 'fertilizer', a complete reorientation in planning production of fertilizers will have to be adopted, in keeping with the concept of supplying both 'Food' and 'Nutrient' to the multitudinous vegetable kingdom and the teeming millions of the world's exploding population. In order to define the relative significance of 'Food' and 'Nutrient', the vegetable and animal kingdoms should be considered together in the light of their evolution in this planet. The mechanism of evolution has, therefore, to be analysed and thoroughly understood to define clearly the functions of 'Food' and 'Nutrient' respectively.

According to the theory† of Universal Spherical Wave of the Energy Field of the Universe, evolution starts from a cause. If the cause is of infinite magnitude of intensity, it can create a configuration of infinite magnitude of size. But for creating a finite configuration of the evolutionary wave, the cause requires appropriate dimensions, varying in magnitudes of intensity and size of configuration, to be incorporated in generating the whole wave and establishing equilibrium therein. The evolution of vegetable and animal kingdoms, following the principles of the spherical wave, requires a certain dimension to start with, emanating from a cause. The cause, in its absolute or fundamental dimensional state, is, of course, not conceivable; but in the finite form, it requires certain dimensions which physically constitute the configuration of vegetable and animal life. *In the mechanism of evolution in the light of spherical wave of energy field, the fundamental dimension*

starts with another opposite derived dimension both associated as one homogeneous inseparable whole.

In the configuration of the Universal Spherical Wave as shown in Fig. 1, this evolutionary state of existence of oneness starting with highest of one and least of the other progressively changes till they arrive at a limiting state of equality, where the fundamental and derived dimensions as well as their containing dimensions, all acquire magnitudes of equality (i.e. equality equilibrium state). The energy field of the universe, beyond this state of existence up to the boundary, exists as a heterogeneous zone in which 2 exist in two different phases in equilibrium—one converging in magnitude of size of configuration but increasing in the intensity of the content of derived dimension and the other increasing in magnitude of size of configuration with the content of fundamental dimension energy progressively decreasing in intensity to nil. Thus the universal spherical wave of evolution should give the clue to the mechanism of the process of evolution in which two enti-

†Chakravorty, K. R., *Energy Field of the Universe and Atom, Part II—Theory of Universal Spherical Wave and Modern Science, Technol;* 2 (1965) 4, Spl. Issue, 244.

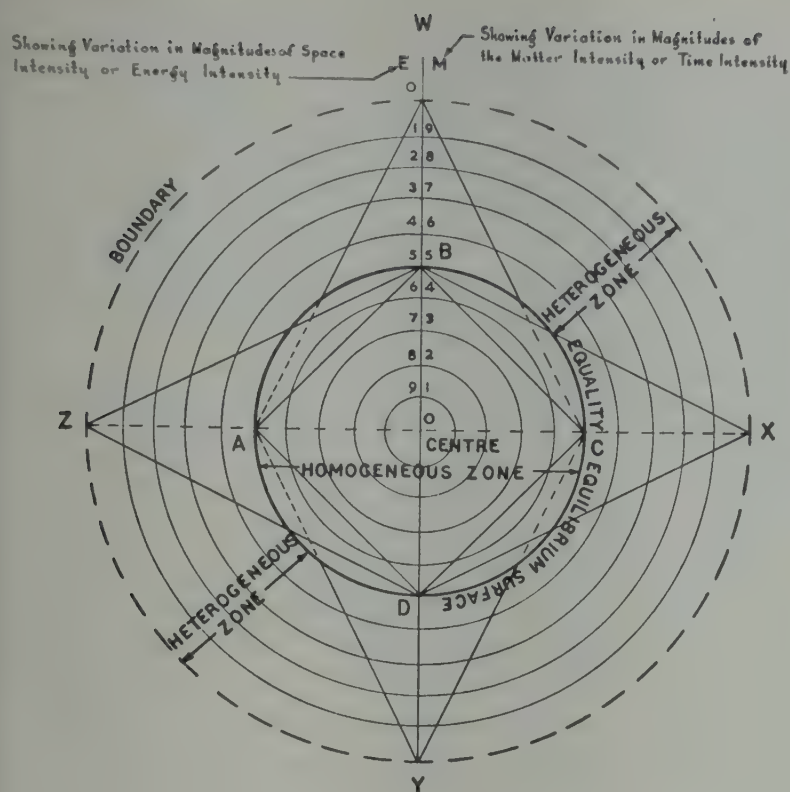
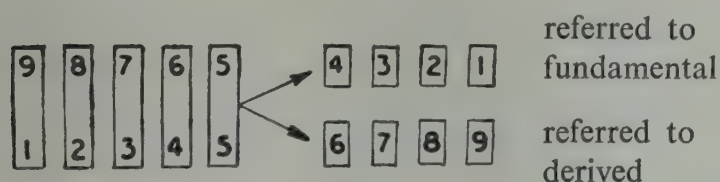


Fig. 1.

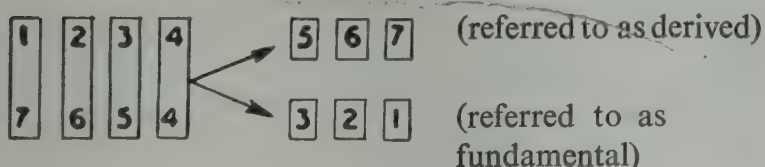
ties existing as one whole but having opposite dimensional significance arrive at a magnitude of equality from which state the two separate and where from the size of configuration of one dimension converges to a position of highest intensity of contained dimension, while the magnitude of size of configuration of the other diverges towards a boundary limit where the intensity of the contained dimension falls to nil. Applying numerical magnitudes to the dimensions, and if the evolution is tetrahedral (4 directional), the evolution will numerically follow the decimal system—as



Two as one

Two separates

If evolution is radial and uni-directional, the representation of evolution by numerals in the Octet system is:

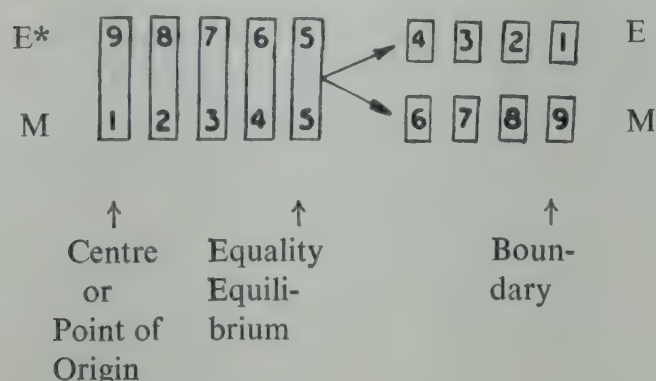


The latter conforms to the periodic system of elements in its second and third periods of classification. If same would be applied to the evolution of plant and animal life, the two dimensions must be associated in one form to begin with and the physical concept of this state of existence would be a perfectly homogeneous fluid in which positions are indistinguishable, viz. water or jelly-like substance in which the whole appears as one and no perceptible differentiation can be made between one position and another, and separation into two individuals is not possible. Whatever dimensions are involved, they are together and vary also simultaneously with the others associated and unsegregated. This jelly-like state of existence in evolution would continue in the light of the spherical wave theory upto a limit which is called the equality equilibrium state in which the dimension causing the evolution and the induced dimension assume a kind of equality in intensity and the configurational dimensions also assume equality of magnitude.

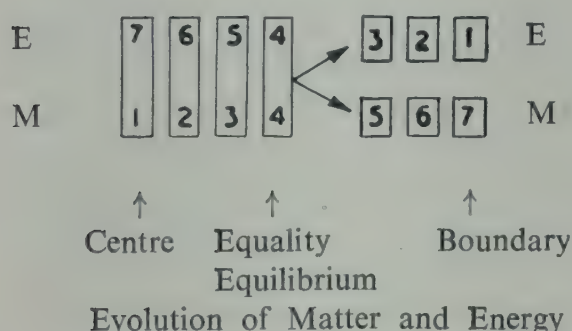
To clarify this aspect, we must refer to the configuration of the universal spherical wave of energy field in Fig. 1. It may be noted that, within the equality equilibrium surface, the magnitudes of intensity of the fundamental dimension and the derived dimension vary in opposite direction, no doubt, but they vary in one homogeneous whole upto the equality equilibrium surface. From the equality equilibrium, however, the derived dimension like matter varies in segregated forms from the medium of space containing fundamental energy. The intensities of the two vary in opposite direction in the heterogeneous zone. The space energy intensity reduces till it is least at the boundary. From the equality equilibrium, space, enclosed in the space energy cone, diverges towards the boundary whereas the space, enclosed within the cone, representing matter, converges towards the boundary at one position viz. X.

To all intents and purposes, for explanation of any specific phenomenon in the finite manifested universe, from the equilibrium equality surface towards the boundary, consideration of only one triangular face of a tetrahedron in one direction can be employed. In this, from the equality equilibrium where the 2 dimensions, fundamental and derived, were in their equality state as one, they separate and while one converges in segregated form, increasing in magnitude of intensity, the other decreases in magnitude of intensity such that at the boundary the former becomes highest, and the latter the least. From the centre upto the equality equilibrium (in the homogeneous zone,) the fundamental and derived would vary, starting with

highest and least intensity respectively, till they reach the equality equilibrium both in combination as one indistinguishable whole. This is represented figuratively in the decimal system:



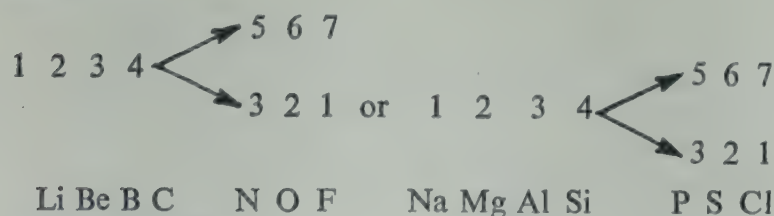
In the octet system:



(Assume energy and matter as the fundamental and derived dimensions respectively.)

The most important significance of the configuration is that the two start in the evolution as one inseparable form which, after attaining certain equality equilibrium intensity with respect to each other, they separate out, one of them increasing in intensity and the other decreasing till they attain their highest and least magnitudes at the boundary.

These, instead of assuming the dimensions as energy and matter, can as well be taken as some perspective properties of a dimension, e.g. elementary matter or chemical compound or life (as exhibited in animal or vegetable kingdom). For example, in the periodic system of classification of elements, in the second and third periods, the valency property of the elements in periodicity varies as octets as mentioned in the above.



* E=Energy.
M=Matter.

It may be seen that at equality of 4, carbon or silicon has its combining potential with basic elements like hydrogen and acidic elements like oxygen equal i.e. 4 and 4. In the 5th group, for phosphorus or nitrogen, the basic characteristics diminish to 3 and acidity potential increases to 5 (which was 4 for carbon). Similarly for 6th and 7th, their valency potential for combination with basic elements is 2 and 1 and with acidic elements 6 and 7 respectively.

Take the elements in the second and third periods of the periodic table:

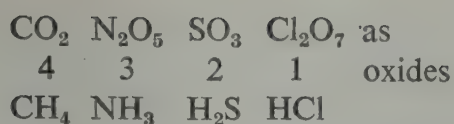
Li	Be	B	C	N	O	F
Na	Mg	Al	Si	P	S	Cl

The elements in the first, second, third and fourth groups are like the stages of development in the homogeneous zone of the spherical wave upto the equality equilibrium. The elements C and Si, symbolise equality of opposite properties like +ve and -ive valency e.g. combining capacity towards O_2 and towards H_2 or acidic or basic or electro-chemical properties, etc. The elements in the alkali metal group like Li, Na have themselves the most basic property and the least acidic property. Be and Mg, in the second group, get reduced in basic properties relative to Li and Na; Boron and Al, in the third group, further reduce in basic properties and develop more acidic properties. C and Si represent equalisation of basic and acidic properties. Whereas in the 4th, 5th, 6th and 7th group, each element exhibits two distinct forms of their existence for their acidic and basic properties, the elements in the first 3 groups, in their compounds, themselves exhibit both characteristics in one viz. Boron and Al, which are amphoteric, can share both the acidic and basic properties. If the second and third period of elements would be described in terms of their basic and acidic properties, the 7 groups could be represented in the increasing or decreasing order of numerical designations for these opposite variations and would be indicated in the following:

Acidic	1	2	3	4	5	6	7
Basic	7	6	5	4	3	2	1
	Li	Be	B	C	N	O	F
	Na	Mg	Al	Si	P	S	Cl

Their combining capacities in conformity with the above are shown below as also their distinctiveness/individuality:

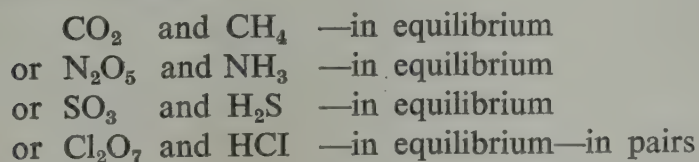
These are not realised in practice	$\overline{CO_3}$	$\overline{NO_3}$	$\overline{SO_4}$	$\overline{ClO_4}$	as ions
<div style="border: 1px solid black; padding: 2px; display: inline-block;">7 6 5</div>	4	3	2	1	
1 2 3	4	5	6	7	



From Li to C, the elements exhibit their two opposite characteristics as one, whereas from C onwards they exhibit opposite properties as 2 distinct compounds like (CO₂, CH₄), (N₂O₅, NH₃), (SO₃, H₂S), (Cl₂O₇, HCl) etc. etc.

It may be noted that, during the process of evolution of elementary matter position associations from one group to next, from the equality state of elementary matter, the direction of compound development from fourth group elements like C or Si, through N₂O₅ or P₂O₅ in the 5th group, sulphur and oxygen as SO₃ or O₃ in the 6th and Cl as Cl₂O₇ in the 7th in one direction and NH₃ or PH₃ in the 5th group, H₂S or H₂O in 6th and HCl or HF in the 7th group in the other is very significant. The elementary matter, in association in compounds for the groups in one direction, associates other elements such that the significant elementary matter of the group loses its individuality in the "complex compound" or coordinated complex and reveals itself in the form of combined configuration which does not show up its individuality, but as complex ions as PO₄ or SO₄. In the other direction, the matter elements starting from equality state, progressively develop towards more distinct individual state of existence as ion.

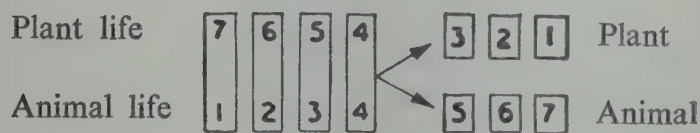
Just for example:



This aspect of evolution is very significant and important from the point of view of progressive evolution in stages towards equilibrium existence of plant life and corresponding animal life.

Other significant properties could be considered in the same manner. These evolutionary characteristics can be applied to animal and plant life as they exist in equilibrium manifestation on the surface of the earth. Both animals and plants possess life. Fundamental dimension—life or consciousness is the cause and, in the finite manifestation, the fundamental associates with two derived opposites, viz. animal and plant life. If the evolution of life in these two manifestations would be amenable to explanation in the light of the concept of evolution of the spherical wave, as mentioned in the above, they should then follow the same sequence of evolution and associated character-

istics, as in the configuration of the universal spherical wave.



Manifested
as one whole

Separates
out

Evolution of Life with Opposite Dimensions

Animal and Plant Life

In this treatment, we have assumed animal and plant as two opposing dimensions. According to the development of the configuration of the universal spherical wave, it requires manifestation of the fundamental as derived dimensions in the configuration such that the variations are opposites in magnitude of size and intensity since equilibrium can only be established between opposites. If the theory of universal spherical wave would be applicable to explain the equilibrium manifestation of animal and plant life on the surface of the earth, it is essential that these two be of opposite dimensions. It, therefore, requires to be established by the associated properties of these that they are opposite in their functioning and characteristics.

While illustrating by analogy, similarity of mechanism of the phenomenon of catalytic chemical equilibrium to plant and animal equilibrium on the earth's surface was mentioned in the paper entitled 'Mechanism of Catalytic Chemical Reaction in the Light of the Universal Spherical Wave of Energy Field'*. On the earth's surface, there are two important variables, animals and plants, possessing the property of life and which can be distinguished from dead inanimate matter. Both the vegetable and animal kingdoms possessing life are composed of inanimate matter in combination and possess configurations constituted of elementary matter only in our perception.

But what we perceive by our experience is not all; there are other associated aspects, which are not realised in our perception. While the chemical composition, the configuration (as crystalline forms) etc. which can be seen, can be experimentally realised and are amenable to one or other forms of physical perception, the aspect of 'life' is not perceptible. This has to be conceived of, as inanimate matter plus 'some thing'

* In this issue p. S16

like consciousness associated in configuration, to make the whole equilibrium concept of life associated with matter varying between plant and animal extremes.

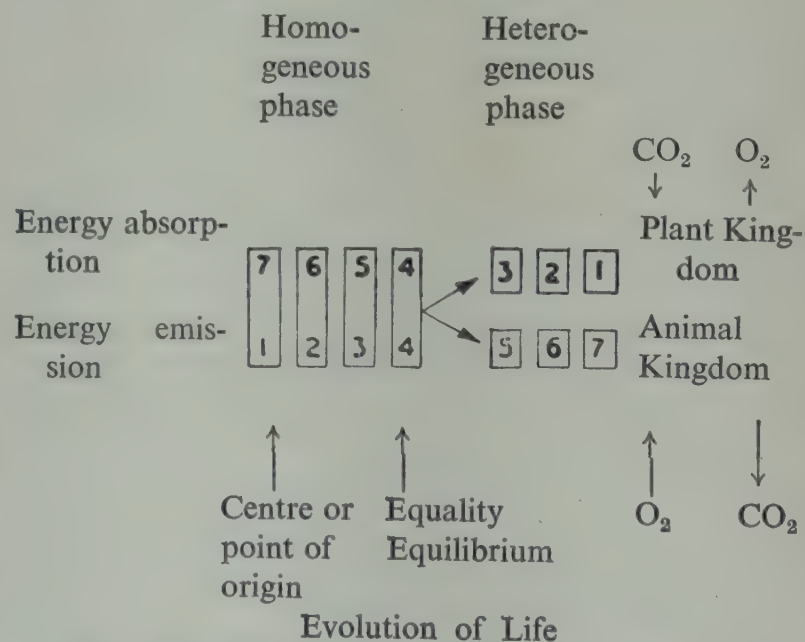
Directions of Development of Animal and Plant Lives are Opposite in Nature

The following would broadly explain functioning of vegetable and animal kingdom as two opposites. The earth's surface consists of solid, liquid and gaseous inanimate matter positions in combination with one another and supports the living entities like plants and animals. Equilibrium is established amongst these three: earth's surface, plant and animal life.

In accordance with the principle of spherical wave of the energy field, the first advent of life cause was associated with the ability to absorb and entrap energy in utilisable form by a configurational entity. The subsequent release or emission of this energy for metabolic processes has made the continuation of the same cause possible. Thus the property of energy absorption and its subsequent emission from biological entities are two significant aspects which are no doubt opposite in character. With progress of evolution the development of life takes place in such a manner that absorption of energy is progressively reduced and emission of energy progressively increased till it reaches an evolutionary equality equilibrium state where the absorption and emission of energy equalise. Upto this state, according to the theory, the evolutionary development is homogeneous. Beyond the equality equilibrium, the evolution takes place in two different directions in a separated manner, i.e. in two phases. The two developments must take place in opposite direction to one another. If one development occurs with highest absorption and least emission of energy, the other takes place with the highest emission and least absorption of energy. The other associated properties during these two developments will naturally follow and may tend to complicate the trends but these two essential characteristics will be maintained.

As we see today, the plant kingdom represents the first and animal kingdom the next in sequence in the direction of evolution. This is substantiated by the fact that plants are generally associated with the absorption of energy and thus have made the surface of earth a storehouse of the energy in available form. This would not have been possible, had not the energy absorption by plants far exceeded that of energy emission, the characteristics of animal are just the opposite. The emission of energy from them is higher and is less credited with its absorption.

The phenomenon of carbon fixation by green plants with the help of light energy (Photo-synthesis) is the most important energy absorbing process in which carbon dioxide is taken in but oxygen is liberated. Though the subsequent release of energy takes place in plant cell itself during the metabolic processes, such as respiration, the amount of energy absorbed and entrapped is far greater than that released in subsequent stages. In animal systems the energy absorbing mechanism is least prominent while most of the vital processes are dependent on the release of energy entrapped in some readily available form, i.e. food, which must be obtained from plants. The external manifestation of this process is reflected by the drawing in of oxygen and liberating carbon dioxide from animal system. These two significant aspects of plant and animal lives are important factors in maintaining the balance of concentration and the total amount of oxygen and carbon dioxide in the earth's atmosphere. Suppose, if the atmosphere would be such that it would start increasing in proportion of CO_2 upto a certain extent and reduction in concentration of oxygen, then the abundance of plant would be increased and correspondingly the abundance of animal life would decrease. Similarly, if there would be increasing concentration of oxygen in the earth's atmosphere and decreasing concentration of carbon dioxide, the plant life should progressively diminish and abundance of animal life should increase. The magnitude and direction of variation of these properties can be represented in the following:



The above representation follows the evolutionary sequences as per principles in the theory of universal spherical wave of evolution.

The development of the 2 characteristics in one phase

between the centre or point of origin and equality equilibrium for animal and plant life is most obscure. But in this phase, there must be some attributable cause to animal or plant life, the chemical constituent and other configurational existence, one aspect of which is amenable to perception and the other only realisable in conception but not realisable in perception. In the existence of vegetable life, it (cause) will vary in opposite direction in its magnitude with that of animal life, starting with the least of one and the highest of the other till those two are evolved as one of equal magnitude. As a hypothetical case, in this homogeneous phase of existence where the two are not distinguishable, in any positions it could give the appearance of a homogeneous fluid like water or a solution or even the form of a viscous uniform homogeneous jelly-like entity. The significance of this is that the system is so homogeneous that it cannot be segregated into two distinguishables. In segregated states of equilibrium existence, life would manifest as animal life due to progressive association, in their developing configurations, elements like carbon and phosphorus in their acidic forms; the vegetable life can be due to progressive association of elements like carbon, nitrogen and phosphorus in their basic forms etc. in its configuration. During the homogeneous phase of evolution upto the equality state, there will be development of biological cells, which ultimately will be responsible for the segregated plant and animal life; at the equality equilibrium state, the cell development must arrive at a state with properties of animal life and plant life of equality. With further development, the segregated entities in equilibrium association with the surrounding atmosphere of chemical constituents with their changing configurations constituting various phases in equilibrium with changing energy intensities of space etc., should develop further in two opposite directions, one towards plant life and the other towards animal life. If plant life would develop with its various associated properties in one direction, the animal life should progress in evolution in the opposite direction with all its associated properties. From the equality state of equilibrium, the life, by opportunity of further association with chemical constituents in their configurations, should separate out during their development towards plant or animal life. Under constant conditions, however, if there would be no external agency working upon the earth's atmosphere effecting any change in the relative rate of energy absorption and emission which is again controlling the equilibrium concentration of carbon dioxide and oxygen, the abundance of animal and plant life should

continue to remain constant. But, since in the energy field of the universe in general and in the solar system in particular, the various planetary bodies are not maintaining constancy, and are undergoing continuous changes, no situation can be conceived of in the universal context as possessing permanent constancy. In the solar system for example, earth, while orbiting along the surface of a cone with the sun as its apex, is progressively shifting away from the Sun. Its climatic condition changes progressively and so also the atmosphere. Naturally, the relative abundance of vegetation as well as animal life will also change. It has already been mentioned in Vol. 2,[†] that configuration of life as such, as is known in plant and animal kingdom on earth, cannot be identical with that of Venus or Mars. The three planets with respect to the Sun are situated in space of different intensities of energy possessing different atmospheric conditions and their relative equilibrium states and abundance of life as vegetable vs. animal kingdom would also be different.

As a hypothetical case, it may be assumed that the life cell in its equality equilibrium state between its plant and animal life potentials, might contain certain elements like C, P, N₂, O₂, H₂, and some mineral matter having certain configuration in a certain environmental condition of uniform homogeneous state of existence. If, from this state, the cell would start, taking in progressively increasing proportion of some form of matter positions of elements or compounds like acidic phosphorus, fatty carbon, protein, Ca and other minerals to assume certain configuration, its development would take evolutionary shapes and forms towards, say, animal life. In the other case, constitutionally and configurationally from equality equilibrium state, the cell might progressively associate more nitrogenous (chlorophyll) and carbon compounds (carbohydrates) and less minerals and phosphorus than in the first case; then its development would take place in the direction opposite to that of animal life. Its further development would lead towards the distinct evolution and formation of plant life.

Not only this, there may be other properties which might associate themselves during cell development in opposite directions as in these two cases. For example, in the development of plant life, photosynthesis takes place through leaves, a process which absorbs light or energy, which would be endothermic. In the other

[†] Chakravorty, K. R., *Energy Field of the Universe and Atom, Part II—Theory of Universal Spherical Wave and Modern Science, Technol.*, 2 (1965), 4, Spl. Issue, pp. 244-45.

case, the reaction would take place in the opposite direction, viz. it should be exothermic. The latter should emit light or energy in the process of its development. Though the principle of photosynthesis seems to have been somewhat understood, present knowledge does not seem to have established whether the exothermic phenomenon is responsible for biological cell development towards animal life. Incidentally the emission of light in terms of biological luminescence has been observed in lower forms of animals like fireflies, glow-worms, centipedes, milli-peds, earth-worms, snails including some bacteria. Although photosynthesis could be stated as the characteristic of plant life, with absorption of photons, it has not been similarly definitely established that cell development towards animal life is associated with emission of light, or is an exothermic process. The state of equilibrium existence of plant and animal life, however, would require that the cell development in the two cases would be opposite and in all probability the cell development towards animal life is exothermic which is opposite to the light-absorbing process of photosynthesis. It is significant that bio-luminescence phenomena, as observed, are generally associated with configurations which are prevalent in the animal kingdom and not in vegetation. It is a common knowledge that, in the animal constitutional system, the overall reaction is exothermic and heat flows from the core to boundary skin. The opposite occurs in plant life, i.e. heat flows from the boundary to the core. The animal also possesses higher inside temperature than the plants.

Another aspect of cell development in animal life could be the progressive development by reaction which is centrifugal, i.e. from the core outwards. In the other case, the progressive development takes place by reaction near at the surface towards development of core, a process which is centripetal. In the developed plants, the nitrogen containing chlorophyll on the leaves is a catalyst which, by its specific action, fixes carbon dioxide as well as photon along with water as food for the plants for their growth and sustenance. In the case of the animal cell development, the reaction seems to be from inside in which, just like dynamic equilibrium configuration in catalytic phenomenon, the animal cell in equilibrium configuration, vibrating between the opposite phases (compression and expansion), converts reactants to products. The heart, the lungs, and the digestive organs all conform to this type of dynamic catalytic equilibrium configuration.

This leads to the two distinctive functions of cells during their development—the function of chlorophyll

in plant leaves on the one hand and the function of the heart, the lungs, and the digestive system in animal life on the other. If the chlorophyll of plant leaves is the catalyst for plant growth, so also the lungs, the heart and the digestive system are the catalytic configurations for animal life for its growth. If the catalysts are active and food available, both plant and animal lives maintain growth and sustenance. If the catalysts only are active and no food is available, growth and sustenance of both are stopped. Similarly, if food only is available and the activity of catalyst is lost (the vitality of organs like the heart, the lungs and the digestive system is lost in animal life and the activity of chlorophyll in plant life) the effect is same as in the former case. For growth and sustenance, both the activity of catalyst and the availability of food are essential; one, in the absence of the other, is of no use.

The important problem is: what is responsible for the activity of the catalyst in the case of plant and animal lives. For a catalyst in a chemical reaction, the activity of configuration is the cause. For animal and plant life, the factor responsible for the activity of the catalyst is the 'nutrient'. This will be discussed later.

The other distinctive properties of the cell development towards these 2 opposite directions are: in animal cell development the progress occurs during evolution in association with inorganic matters towards increase of mineral constituents, progressively more association of particularly P, Ca, fats, proteins, in its configuration, whereas in plant life, the progressive association is more towards increase of C, H, O and carbohydrates than mineral constituents.

A few other points of opposite characteristics of the 2 developments are: the activity of animal is centre-oriented through the heart, lungs and digestive organs, etc. Plant is energy absorbing and animal generally energy emitting.

Another interesting aspect, in the light of the universal spherical wave, is that, since the plant cell development takes place with absorption of energy, the surrounding space intensity would require to be higher for its development, than in the case of cell development towards animal life which would require lower space energy intensity (lower temperature). This would give a clue to the sequence of development of plant and animal life. In the solar system, the various planets have been progressively moving away from their emanating source, the Sun. All the planets are receding from the Sun so that any planet, at a certain state of existence in orbit, has certain atmospheric conditions

of temperature, pressure, composition of elements, the magnitudes of matter intensities of the atomic elements, etc. which change with time orbit. The planets nearer to the Sun would be situated in orbit in surrounding space of higher intensity of energy and the planet at a greater distance from the Sun would be situated at a space of lesser energy intensity; the former in a temperature which is higher with corresponding associated atmospheric conditions and the latter at a lower temperature having corresponding associated atmospheric conditions. The question whether animal life or vegetable life came first in the evolution would be answered from this. Since plant absorbs energy it must be generated in a space of higher intensity of energy to be followed by generation of exothermic animal life at a lower energy intensive space to counter the plant action. While plant apparently can feed on only inanimate materials, the animals can only survive by feeding upon food sustained by vegetation. The sequence of these actions and reactions is thus clear.

Another aspect is that, whereas vegetation is carbon intensive in the core, but nitrogen and phosphorus intensive at the surface, animal life is phosphorus and mineral intensive at the core and carbon-nitrogen intensive at the surface (skin).

From the above discussion, it would be clear that, for the growth and sustenance of plant and animal life in their evolutionary sequence, different kinds of development, which are mostly opposite in nature for the two, are required. Animal development is phosphorus intensive at the core and plant development is associated with intensive accumulation of C, H and O₂ at the core. Exothermic development in animal life leaves the core less energy intensive and more matter intensive. The endothermic development of plant leaves the core more energy intensive and less matter intensive. (This is easily verifiable from the amount of heat energy available when animal body is burnt, compared to that of corresponding amount of vegetative material.) Animal body building is associated with more complex grouping in which the elementary matter constituents enter into complex configurations in which individuality of elementary matter is lost far more than that in the development of plant life. For the growth and sustenance of animal life, food, required for their metabolism, is more complex than those required for the plants. Further, the complex food for the animal should also be associated with relatively more mineral matter. For the plant, the food is relatively simple, viz. carbon dioxide+water vapour or carbonic acid (H₂CO₃). Main assimilation of plant food takes place through

the leaves, although the root also provides an important organ for the plants for assimilation of food, particularly for assimilation of its mineral constituents.

Whatever be the nature of food in the two cases, if there would be malfunctioning of the organs, (e.g. digestive, assimilative systems, etc. in the animal being, and chlorophyll in plant life), then they would not grow properly. There would not be either proper functioning of the chlorophyll of the leaves or proper functioning of the plant leaves as such or the vital organs in animal life will not function properly, if nutrients are not supplied, however much food can be made available; neither there will then be proper assimilation of food and simultaneous growth.

Problem of supply of plant food and nutrients

In the vegetable kingdom the chemical analysis of plant tissues would show that 60-90 per cent of the fresh weight is due to water and 45-50 per cent of the total dry solid matter is carbon. Nitrogen, phosphorus and other elements constitute only smaller fraction of the total weight. Thus for body building and growth, plant food is mostly carbonaceous which must be provided from the atmosphere and soil. But the function of nitrogen, phosphorus, etc. lies in the operative organs like leaves or roots. At the outer layers of leafy tissues assimilable nitrogen, Mg, Fe, Cu, Zn and Mn, etc., with the assistance of light energy, provides the activity of the chlorophyll, just like an equilibrium catalyst configuration, to absorb carbon dioxide and water vapour from the atmosphere. Similarly, some mechanism also perhaps occurs in the roots which is more obscure. It is not difficult to see the role of these elements like nitrogen, phosphorus, potash, Mg, Zn, Fe, Mn, Cu, etc., in their assimilable form of chemical compounds for the plants. These mainly serve to promote and keep up the activity of the food assimilating organs. They themselves are not food for the plants but are nutrients. Vegetation for its food mainly requires assimilable carbon. So far as is known, this is mostly absorbed through leaves from the atmosphere in the presence of adequate moisture. But evidence is available to show that the assimilation through the root is also not negligible. The root itself also plays an important part in plant growth. Plant food must, therefore, also be present in the soil. As mentioned previously, since carbon forms the major elements for plant food, there must be an abundance of assimilable carbon both in the atmosphere and in the soil.

We have now come to the conclusion that, for large-scale food production, the presence of carbon in the

atmosphere all over the land in the country must be adequate. Further, requisite amount of assimilable carbon in the soil is also simultaneously required. The generation of assimilable carbon in the soil is obviously not transferable from one part of the country to another or, for that matter, from one country to another. But how far the presence of a certain quantity of carbon-dioxide in the soil in one country and in the atmosphere also, can transmit its effect to another country at a great distance requires to be probed and in all probability, unless there is natural atmospheric current flowing between the two countries, existence of carbon dioxide in one spot need not help or replenish carbon dioxide in another atmosphere which is deficient.

Besides the natural causes, there are several other means of increasing carbon dioxide in the atmosphere, viz. burning of carbonaceous fuel in a country in the industrial plants; again, normal seasonal decay of carbonaceous matter also can contribute carbon to the atmosphere. In this context, it should be examined whether in manufacturing a primary product like ammonia, which is a plant nutrient, in one country on the surface of the earth, the carbon dioxide, evolved in the process as by-product and released to the atmosphere where ammonia is manufactured, would help a distant country as plant food or not. For every ton of nitrogen produced as fertilizer the associated production of carbon dioxide, of course, depends on the type of raw material chosen. In case the raw material is naphtha, per ton of nitrogen production about 4.2 tons of carbon dioxide are also produced simultaneously. If the raw material is coal and power generated thermally, per ton of nitrogen production, there would simultaneously be produced as much as 15 tons of carbon dioxide and released to the atmosphere. This analysis reveals two important facts. Firstly, it immediately gives us a clue as to which raw material should be preferred for production of nitrogen fertilizer in order to yield more carbon dioxide to the atmosphere to be available as plant food. The answer obviously is coal. Secondly, whatever be the raw material resources, it is obvious that the generation of nitrogen must also be associated with the generation of by-product carbon dioxide. It is, however, immaterial whether this carbon dioxide is re-used to produce a finished fertilizer like urea containing carbon dioxide or it is released to the atmosphere; the ultimate result would be the same. But what is important is to provide industrial gases with more carbon dioxide for more abundance of plant growth and also the production of nitrogen and carbon dioxide simultaneously as plant nutrient and plant food respectively in the in-

terest of the country's self-sufficiency in both.

Now, if it is proposed to use ammonia, manufactured in one location on the earth's surface, in another quite far away country unless enough carbon dioxide exists in the latter atmosphere, more application of ammonia will not help additional vegetation or food production. The proposal, therefore, by the World Bank to produce ammonia in the oil fields and supply it for fertilization and increasing food production in other countries or manufacturing ammonia in one location and exporting it to another for basing fertilizer plants containing nitrogen only or even another nutrient like P as NP, NPK, will serve very little purpose if enough carbon dioxide in the atmosphere with associated water vapour (humidity) is not simultaneously supplemented, or is not originally present in the atmosphere as well as in the soil of the importing country. The planning for fertilizer production for a country for increasing its food output therefore, requires a careful examination of this point, so that balanced planning is ensured not only for generation of fertilizer nutrient capacity, but also for plant food potential simultaneously. We have shown in the above that for growth and sustenance of plants the plant food must be available in the atmosphere as well as in the soil. In countries, particularly in tropical climate, the soils get more quickly depleted in carbon content. In India, due to erosion of soils in many parts, the soil has been left depleted in assimilable carbon content. To bring up the carbon content of the soil to the adequate levels and to render the soil efficient for vegetable growth, assimilable carbon requires to be artificially replenished. Cowdung, compost, oil cakes and other conventional means alone will not meet this requirement. The only alternative seems to be to process the reserves of coal, lignite or peat, if available anywhere and these only can be used to supplement this requirement. The most important thing, therefore, is to develop the most economic process of rendering these materials into assimilable forms to be applied extensively in these regions where soil is depleted in carbonaceous matter. Application of urea and ammonium bicarbonate to the soil from this angle, i.e. for supply of plant food and not merely plant nutrient, has to be given serious thought. From this point of view it appears that ammonium bicarbonate should be more desirable for the simultaneous supply of both plant nutrient and plant food to the soil, even more than urea, since its C/N ratio is higher. Concerted and all-out efforts need to be taken in the direction of transforming coal, lignite, etc. to assimilable forms and their direct application to the soil.

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Gas Chromatographic Separation of Low Boiling Pyridines Using Liquid-Coated Silica Gel Column

By

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Retention behaviour of pyridine bases has been studied with glycerol-coated silica gel columns. The order of elution has been found to be different from glycerol-on-inert support columns and in accordance with boiling points. This peak reversal has been found to be due to a distinct separation force—originating from strong interaction between pyridine homologues and silica gel—which works in opposition to the partitioning forces of glycerol. It has been suggested that suitably modified silica gel might be useful in the analysis of nitrogen heterocycles.

Low boiling pyridine bases are important raw materials for valuable drugs and pharmaceuticals. The main source of these nitrogen heterocycles is coke oven liquor which should be analysed first for the individual pyridines before any assessment of their recovery potential can be made. A method of separation and estimation of quinoline and isoquinoline¹ has been developed in this laboratory. In the present study gas chromatography was chosen as a separation technique because of its numerous successful applications in the separation of all kinds of isomers, including the isotopically substituted ones. The classical work of James and Martin,^{2,3} as early as 1952, included the first application of gas-liquid chromatography (GLC) on pyridine homologues. Thereafter, many stationary liquids⁴⁻⁶ were tried, but only the polar ones were found to be effective. Mention can be made, in particular, of the work of Brooks and Collins⁴, and Murray and Williams⁵, who used glycerol as a stationary liquid. Since peak-tailing is a serious limitation in the GLC of many polar solutes, the pyridines in particular, a great deal of work has been done on the pre-treatment or modification of diatomaceous supports^{7,8} as well as on the development of new supports.⁶ Most of these supports more or less reduce peak-tailing even with non-polar substrates, but satisfactory separation could be obtained only with polar liquids.

Structural and polarity differences of the pyridines on selective liquid substrates were the basis of separation mentioned above. An entirely different approach was made by Hanneman⁹ involving the use of eutectic salt-mixture in place of organic liquids on conventional supports. The order of elution of the pyridines was similar to that of glycerol, but the separation was somewhat inferior (as can be seen from the relative retention data).

The main object of the present work is to introduce a different separation force distinct from those of partitioning liquids and inorganic complexing agents. Decora and Dineen⁶ observed that the pyridine homologues emerge at different times from columns packed with bare supports like Chromosorb and Celite as well as from their new product from commercial detergent 'Tide'. It was, therefore, hoped that the replacement of conventional supports with strong adsorbents, like silica gel modified with suitable organic liquids, will bring into play an additional and improved separation force for the pyridine homologues. Glycerol was retained as a modifier and tail-reducer, because of its proven success in the separation of nitrogen heterocycles. A secondary purpose of this study was to find indigenous substitution for the costly and imported diatomaceous supports.

Experimental

Aerograph 600D Hy-Fi, with flame ionization detector was used. 10 per cent (w/w) glycerol was coated separately on 30-52 mesh (B.S.S.), E. Merck chromatographic grade silica gel and 80-100 mesh Gas Chrom-Q using methanol as solvent. The excess solvent was evaporated slowly under an infrared lamp. The coated support was then oven-dried at 110°C for 1 hour and packed into 1/8 inch O. D. copper tubing with gentle tapping with a rubber-padded glass rod. The silica gel column was 150 cm. long and the Gas Chrom-Q column 75 cm. long. Both the columns were coiled to about 8 cm. diameter and closed at the ends with short pads of glass wool. Columns were conditioned inside the chromatograph at 125°C using argon as carrier gas, until the base line was found stable. The silica gel column was run at 118°C with 25 p.s.i.g. pressure of argon at the column inlet and 31.0 ml/min. flow rate at the jet of the flame ionization detector. The Gas Chrom-Q column was run at two temperatures, namely 90 and 118°C, the column inlet pressure being 22 p.s.i.g. in both cases.

Results

Retention times of A. R. quality pyridine, 2:6-lutidine, α , β and γ -picolines were determined separately and individually by injecting 0.1 μ l. liquid samples with a 1 μ l. Hamilton syringe and taking the average of 3 to 5 injections for each compound. The results for the silica gel column at 118°C and for the Gas Chrom-Q column at 118 and 90°C respectively are given in Tables 1 and 2 respectively.

TABLE 1—RETENTION CHARACTERISTICS OF PYRIDINES FROM SILICA GEL-GLYCEROL AND GAS-CHROM-Q-GLYCEROL COLUMNS AT 118°C

Compounds	Boiling Points, ⁶ °C	Silica-gel-Glycerol Column		Gas-Chrom-Q-Glycerol Column	
		Relative Retention	Order of Elution	Relative Retention	Order of Elution
Pyridine	115.3	1.00	1	1.00	3
α -Picoline	129.4	1.67	2	0.92	2
2:6-Lutidine	144.0	1.97	3	0.75	1
β -Picoline	144.1	2.81	4	1.32	4
γ -Picoline	145.4	3.58	5	1.38	5

TABLE 2—RETENTION CHARACTERISTICS OF LOWER PYRIDINES ON GLYCEROL-COATED GAS CHROM-Q, KIESELGUHR⁴ AND CELITE⁵ SUPPORTS

Compounds	Gas Chrom-Q at 90°C		Kieselguhr at 90°C		Celite 535 at 78°C	
	Relative Retention	Separation Factor	Relative Retention	Separation Factor	Relative Retention	Separation Factor
Pyridine	1.00		1.00		1.00	
α -Picoline	0.88	1.51	0.82	1.89	0.88	1.64
2-6 Lutidine	0.67	1.33	0.53	1.55	0.61	1.44
β -Picoline	1.42	1.15	1.54	1.21	1.52	1.22
γ -Picoline	1.64		1.86		1.85	

Discussion

Lower pyridines gave fairly symmetric and tail-free peaks from the silica gel column. An interesting finding in the present work is that the order of elution of pyridine, α -picoline and 2:6-lutidine from silica gel-glycerol column at 118°C is entirely different from Kieselguhr-glycerol column at 90°C and Celite-glycerol column at 70°C (vide Tables 1 and 2). The possibilities for this changed elution order are either the reversal selectivity of glycerol for these compounds due to the use of higher temperature (118°C) or the separation forces of opposite nature originating from silica gel.

(i) *Effect of Support on Peak Reversal:* Using the same amount of glycerol on Gas Chrom-Q—which is thoroughly acid-washed and completely silanized and as such, being more inert than Celite or Kieselguhr, will keep the support effect to a minimum level—it was observed that at both 90 and 118°C (vide Tables 1 and 2) the lower pyridine homologues elute in the same order as found by earlier workers^{4,5} using Celite or Kieselguhr as supports, and in a different order from glycerol on silica columns. These experiments confirm that reversal of elution order from the stationary liquid, namely glycerol, is not due to an increased column temperature.

It is, therefore, established that the separation forces arising out of silica gel support work in opposition to the partitioning forces of glycerol substrate. Using a liquid phase (which is compatible with silica gel) e.g. tri-xylenylphosphate⁴, which gives the same order of elution as the silica gel support, a better separation of pyridine homologues might be expected. An ideal liquid-modifier for silica gel should not only reduce peak-tailing efficiently but also function towards im-

proved separation. Study of separation characteristics with different stationary liquids will throw more light on the nature of interaction between silica gel and liquid phases vis-à-vis sample molecules. The nature of interaction of pyridine bases with silica gel will obviously depend on its chemistry of surface and geometry of pores. The silica gel used in this investigation was of surface area 220 m²/g. Using a different grade of silica gel (10 per cent glycerol-coated) of much higher surface area it was observed that the pyridines are not at all eluted from a 5 feet column at 118°C. The strong interaction between silica gel and pyridine homologues is apparent from their much longer retention time from silica gel glycerol columns compared to equivalent columns containing glycerol on conventional GLC supports.

(ii) *Effect of Temperature on Separation:* The separation factors obtained from Gas Chrom-Q-glycerol column for the pair of solutes pyridine/2:6-lutidine, α -picoline/2:6-lutidine and γ -picoline/ β -picoline are 1.51, 1.33 and 1.21 respectively at 90°C as compared to 1.33, 1.23 and 1.05 at 118°C. These results are in conformity with the general rule that separation is better at lower column temperature. Comparing the same separation factors of 1.97, 1.19 and 1.27 from silica gel-glycerol column at 118°C with the corresponding values of 1.89, 1.55 and 1.21 from Kieselguhr-glycerol column at 90°C, it is probable that the former column will give better separation than the latter when run at the same temperature.

(iii) *Effect of Supports on Column Efficiency:* The values of separation factors for the pair of solutes in the order of pyridine/2:6-lutidine, α -picoline/2:6-lutidine and γ -picoline/ β -picoline are given in Table 2. It is

noted that the relative retentions and the separation factors are more favourably distributed for better separation of pyridine homologues with Kieselguhr rather than with Gas Chrom-Q. The role of support is also evident from the difference in the degree of separation observed with silica gel and Gas Chrom-Q supports at the same temperature of 118°C.

However, the silica gel column needs to be further improved with respect to fastness of analysis and sharpness of peak in order to widen its applicability to higher pyridines. Further work is under way for the selection of specific silica gel, suitable chemical and physical modification of its surface and the choice of a tail-reducer which is compatible with the support.

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Studies on the Strength of Coke

By

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The results on the strength of coke measured by a micro-shatter apparatus and by a small laboratory drum test procedure developed in this laboratory were compared with the standard shatter and micum strength. Micro-shatter index 72 was found to have a close correlation with the $\frac{1}{2}$ inch shatter index. The predicted micum indices from the small laboratory drum test satisfactorily compared the standard micum indices of coke obtained from commercial coke ovens. Coke prepared in the small laboratory carbonization oven, however, indicated a slightly higher strength than those obtained from the commercial oven.

The quality of coke is assessed by a number of tests, and in this respect the primary interest up to the present time has been in the examination of hardness. The nature of coal¹ and their preparation^{2,3}, the method of coking, the dimension of the oven⁴, temperature and period of coking^{5,6}, all have influence on the character of the coke.

The shatter and micum tests are probably the most important of the physical tests of coke. While the shatter test gives the impact hardness, the micum test which is intended to assess the resistance to abrasion of coke is still widely employed in the industry. In the Indian Standard Specification⁷, the hardness of coke is expressed by its shatter, micum and Haven's stability tests. A wide variety of combined indices have been suggested from time to time to cope with the problem of defining coke quality by a single factor⁸⁻¹⁰. A comparative study of the shatter and micum tests has been carried out by the British Coke Research Association. A similar study was made by the Northern Coke Research Committee¹², U.K. The N.C.R.C. concluded from their work that the micum test was virtually a modified shatter test in which the treatment was more drastic than in the latter.

Various small tumbler tests have been developed from time to time. The Nedelman-Trommel test¹³, Simek and Coufalik's laboratory drum test¹⁴ (miniature of the Micum drum) are worth mentioning. Burdekin and Mott¹⁵ have also described a small laboratory scale shatter test of coke. In all these cases, the authors have

tried to correlate the actual shatter and micum tests with their laboratory scale strength index.

Much work has been done in the Central Fuel Research Institute, Dhanbad (India)¹⁶ on a comparative study of shatter, micum and Haven tests with the micro-strength index as recommended by N.C.R.C. For higher temperature of carbonization, a good correlation of drum strength and micro-strength of coke has been explained by J. Nadziakiewicz¹⁷.

In the present paper the coke strength determined by a simple laboratory drum test procedure developed in this laboratory based on Simek and Coufalik's method, was studied and compared with micro-shatter and large scale shatter and micum tests.

Experimental

The samples of coke required for the test were collected from the following sources.

(1) *Laboratory Carbonization Apparatus*: Coke was obtained from carbonization of 1.2 kg. of coal charge in laboratory carbonization apparatus based on Jenker's method under desired carbonization conditions such as carbonization temperature, carbonization speed, coke mass temperature at the end of carbonization, soaking time, bulk density and size distribution of coal charge etc. With this coke only laboratory drum and micro-strength tests were performed.

(2) *Commercial Oven*: Cokes produced in the 350 mm. wide 10 ton capacity byproduct ovens at Sindri were

collected. These cokes were subjected to the shatter and micum tests by the conventional method and also the laboratory drum test and micro-strength tests were performed with these samples.

Test Procedures: The following tests were carried out: (a) Micro-strength test; (b) Laboratory drum test; (c) Shatter test; and (d) Micum test.

(a) Micro-strength test of coke was carried out by the method adopted by the Northern Coke Research Committee¹⁸. In their method 2 g. of representative sample ($-14+25$ B.S. sieve) is charged into a tube 1" i.d. \times 12" long with 12 steel balls $5/16$ " diameter. Two such tubes are mounted at right angles to each other and to the axis of a drive shaft by which they are turned end for end at 25 r.p.m. for 800 revolutions. The results of tests are expressed as percentage of original coke remaining on 25 and on 72 B.S. sieves. In our laboratory for better uniformity of result a closer size grading of coke as between 18 and 22 B.S. sieves was adopted, and at the end of the experiment results were expressed as percentage remaining on 22 and 72 B.S. sieves.

(b) The laboratory drum test machine used for the tests was based on the procedure of Simek and Coufalik¹⁴. It consists of a cylindrical mild steel drum 30 mm dia \times 30 mm long (internal) \times 3 mm thickness, fitted with four lifting shelves 3 mm wide \times 2 mm thickness and welded on its internal wall. 500 g. of coke of a size fraction between 40 and 50 mm round hole screen was charged in the drum which was then closed by a metal flange and bolt system. Rotation was continued at 25 r.p.m. for 1250 revolutions. The contents of the drum were then screened over 10, 20, 30 and 40 mm screens with round holes. The percentages of original coke retained on different screens were plotted. The line joining the 20 and 30 mm points were extrapolated to cut the 40 and 10 mm ordinates which predicts the 40 and 10 micum indices.

(c) Shatter test was performed in accordance with the I.S. specification 1354-1964.

(d) Micum test was also performed in accordance with the above I.S. specification.

Results and Discussion

Repeatability of Micro-strength Index: Experiments were done with 2 g. as well as 5 g. samples ($-18+22$ B.S. mesh) of the same coke for the purpose of standardization. The results are given below (Table 1):

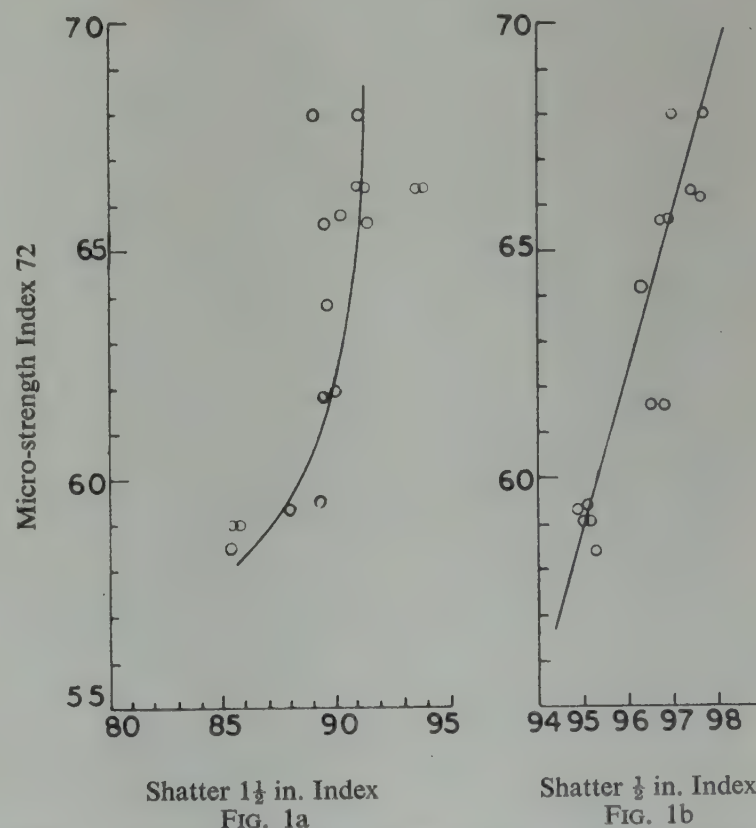
It is observed that the results are almost repeatable within 0.5 units on 22 mesh and 2 units on 72 mesh.

TABLE 1—REPEATABILITY OF MICRO-STRENGTH INDEX

No. of Expt.	With 2 g. Sample		With 5 g. Sample	
	% retained on		% retained on	
	+ 22 mesh	+ 72 mesh	+ 22 mesh	+ 72 mesh
1 (a)	5.1	60.0	7.2	62.4
(b)	4.5	58.0	6.0	60.1
2 (a)	4.9	59.0	7.4	62.5
(b)	5.1	59.7	7.4	62.4
3 (a)	4.1	58.2	7.3	62.1
(b)	3.9	57.8	7.6	62.7
4 (a)	4.7	60.6	7.9	63.2
(b)	5.8	60.9	7.6	62.0
5 (a)	5.3	60.5	7.0	62.3
(b)	5.1	58.0	7.3	62.9

However, percentage fraction retained on both the sieves are higher when 5 g. of sample were taken for experiment. For our present study, 2 g. of sample were used.

Relationship of Micro-strength Index with Other Strength Index: The micro-strength index was found to bear a good relation with $\frac{1}{2}$ inch shatter index. This is evident from Figs. 1(a) & 1(b) in which micro-strength index 72 has been plotted against $1\frac{1}{2}$ inch and $\frac{1}{2}$ inch shatter index. The relation of micro-strength index 72 was found not satisfactory with $1\frac{1}{2}$ inch shatter index.



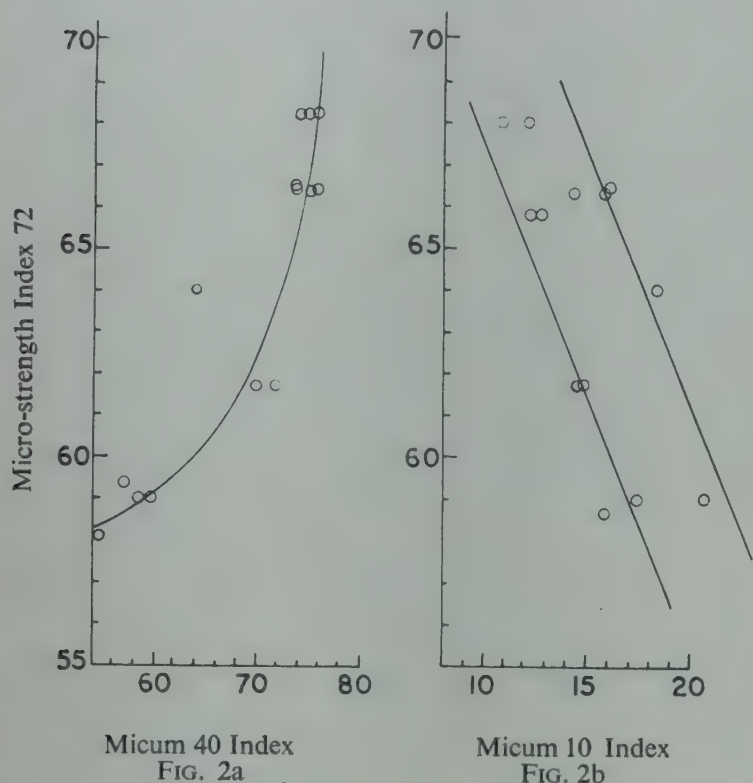
FIGS. 1a & 1b—Relation between Shatter & Micro-strength Indices using Coke Oven Coke

From Figs. 2(a) and 2(b) it could be seen that Micum 40 index can be predicted from micro-strength index 72 satisfactorily. Micum 10 could be predicted, but with a variation of +3 units. The relation of micro-strength index 72 with the percentages retained on 30

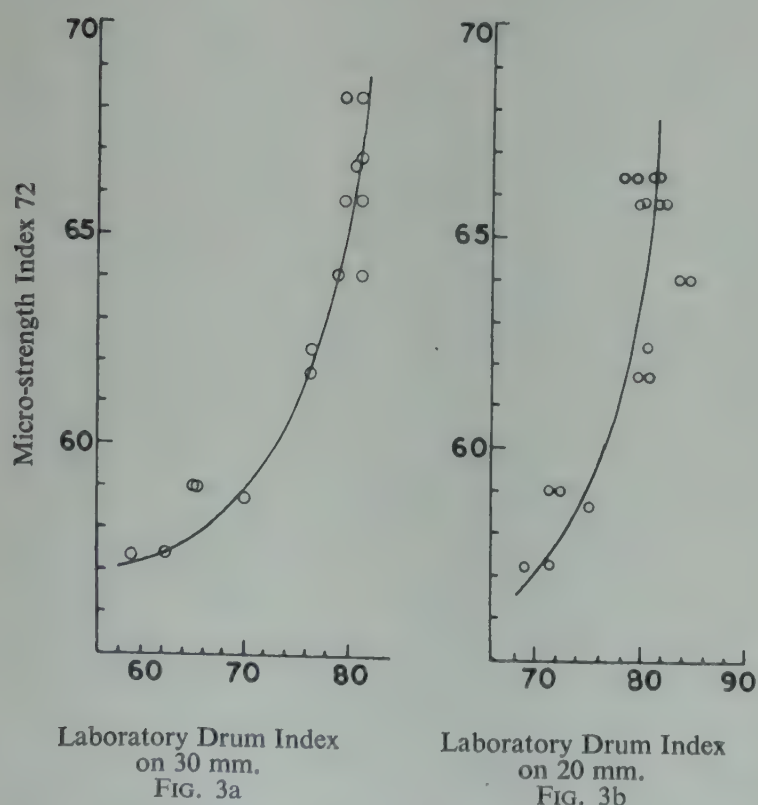
and 20 mm. of laboratory drum test are also shown in Figs. 3(a) and 3(b) indicating fairly good correlation.

All the relations of shatter, micum and laboratory drum tests hold equally good with micro-strength index 22. This is possible because of the close relation between 72 and 22 indices of micro-strength test (Fig. 4).

Prediction of Micum Indices of Plant Coke from Laboratory Drum Test: The results of laboratory drum test are plotted with size of screen as ordinate and cumulative percentage as abscissa. (Fig. 5). The points on the curve corresponding to 30 and 20 mm size are joined and extrapolated to cut the 40 and 10 mm lines on the abscissa. The percentages indicated on these points predict values of 40 and 10 mm micum indices.



Figs. 2a & 2b—Relation between Micro-strength and Micum Indices using Coke Oven Coke



Figs. 3a & 3b—Relation between Micro-strength and Laboratory Drum Indices

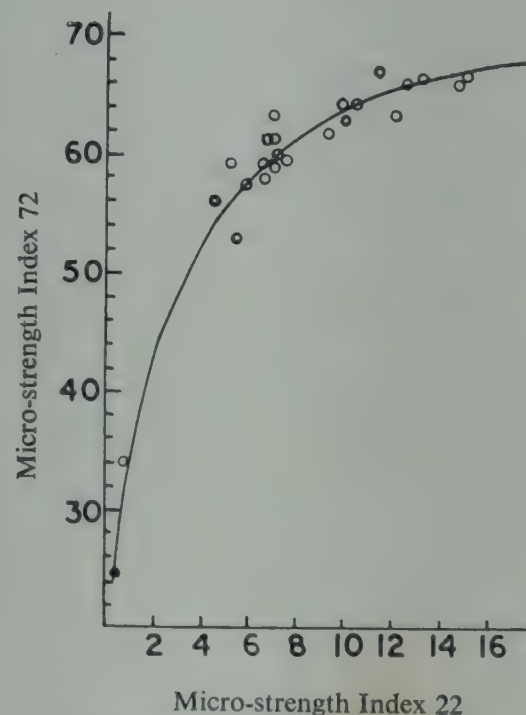


FIG. 4—Relation between Micro-strength Indices 72 and 22

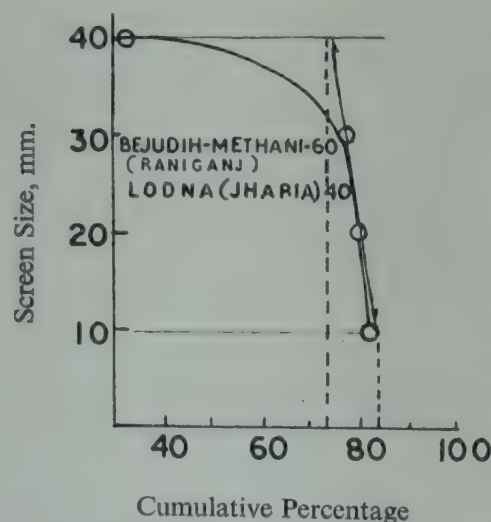


FIG. 5—Plotting of Results of Laboratory Drum Test and Prediction of Micum Indices

In this case the predicted micum indices for 40 and 10 mm are 73 and 16 respectively. The standard micum indices for the same were 70 and 15 respectively. Table 2 gives the comparison of actual micum indices with predicted micum values from laboratory drum test for cokes obtained from the commercial ovens. While the predicted micum index 40 from small laboratory drum test gives fairly similar values as those of standard micum indices, the predicted micum 10 values are observed higher by 1-3 units.

TABLE 2—PREDICTION OF MICUM INDICES FROM LABORATORY DRUM TEST

Sl. No.	Blend of Coal, %	Micum Index		Predicted Micum Index from Lab. Drum Test	
		+40 mm	-10 mm	+40 mm	-10 mm
1.	Bejudih-Methani (Raniganj) 55	71	12	70	15
	Lodna-Loyabad 45 (Jharia)				
2.	-do-	77	12	73	16
3.	Bejudih-Methani 60	67	16	67	16
	Lodna-Loyabad 40				
4.	-do-	63	19	64	17
5.	-do-	64	15	69	16
6.	Bejudih-Methani 55				
	Lodna-Loyabad 45	72	14	68	16
7.	-do-	71	18	72	19
8.	-do-	73	15	74	14
9.	-do-	73	14	68	14
10.	-do-	67	15	67	15
11.	Bejudih-Methani 45				
	Lodna 25	74	15	69	18
	Loyabad 30				
12.	-do-	77	13	77	15
13.	-do-	77	13	77	18
14.	Bejudih-Methani 60				
	Lodna 20	74	12	79	14
	Loyabad 20				
15.	-do-	72	16	67	19
16.	-do-	73	16	68	16
17.	Bejudih-Methani 60	59	20	59	20
	Lodna 40				
18.	Bejudih-Methani 60	70	15	73	17
	Lodna 40				
19.	-do-	70	16	73	16

Although the predicted micum indices from laboratory drum tests of coke from the coke oven plant compare satisfactorily with the standard micum indices, the predicted indices of coke prepared in the small laboratory carbonization apparatus are in most cases slightly

higher than the standard micum indices of plant cokes obtained by carbonization of same blends of coal. Thus, for any blend of coal, if the coke from the laboratory carbonization apparatus shows unsatisfactory strength, the plant coke will always be inferior; whereas for satisfactorily predicted micum indices of laboratory coke, the plant coke is expected to give satisfactory strength.

In all the above results, an allowance should be made for sample error which is more for small size of sample required for laboratory test.

It has also been observed that a close relationship exists between $\frac{1}{2}$ inch shatter index and the abrasion index as determined by micum 10 test. The ratio of micum 10 index and $100 - \frac{1}{2}$ inch shatter index was found to be about 4.5 (Table 3). In view of this result it appears that the $\frac{1}{2}$ inch shatter index would provide a convenient measure of the resistance of a coke to abrasion.

TABLE 3—RELATION BETWEEN SHATTER $\frac{1}{2}$ INCH AND MICUM 10 INDICES

Sl. No.	Blend of Coal %	Coke Property		Ratio of Micum 10 Index and $100 - \frac{1}{2}$ in Shatter Index
		Micum 10 Index	Shatter $\frac{1}{2}$ Index	
1.	Bejudih-Methani 70	12.0	97.5	4.8 *
	Lodna 30			
2.	Bejudih-Methani 60	14.8	96.5	4.2
	Lodna 40			
3.	-do-	14.4	96.8	4.5
4.	-do-	21.6	95.0	4.3
5.	Bejudih-Methani 60	23.8	95.1	4.9
	Lodna-Loyabad 40			
6.	-do-	23.8	94.7	4.5
7.	Bejudih-Methani 45			
	Lodna-Loyabad 25	12.2	96.9	4.1
	30			
8.	-do-	12.2	96.8	4.0
9.	Bejudih-Methani 70	12.0	97.5	4.8
	Lodna 30			
10.	Bejudih-Methani 80	18.2	96.2	4.8
	Lodna 20			
11.	Bejudih-Methani 60	10.8	97.7	4.7
	Lodna-Loyabad 40			
12.	-do-	12.0	97.0	4.0
13.	-do-	11.4	97.4	4.4

*Case 1: $\frac{12}{100 - 97.5} = 4.8$

A comparison of the laboratory test with shatter and micum tests could not be made with cokes having wide variation of strength, as it is difficult to get coke of varying strength from one standard-practiced oven.

Conclusion

The success of strength determination depends much upon the sampling of coke. It also depends upon the methods of carbonization, but for commercial oven when everything is standard, much depends upon proper sampling. The different sizes of coke have different ranges of strength index. Hence, for each test the size of coke should represent the run-of-oven. Coke prepared in the laboratory, being smaller in size and quantity but more uniform in nature, shows slightly superior quality than that in the plant. The micro-strength test gives the intrinsic strength of coke. For micro-strength, consideration of fissuration is much more important. The laboratory drum test is intermediate between impact and abrasive hardness, and it has been found to satisfy both the results.

Acknowledgement

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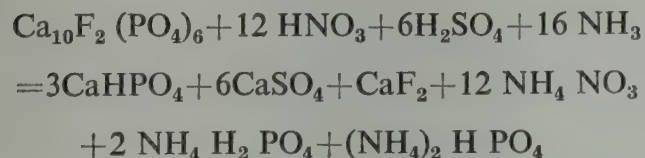
Studies on the Composition and Interactions of Different Phases in Sulphonitric Nitro-Phosphate

By

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Reactions between different forms of calcium sulphate on the one hand and mono- and di-ammonium phosphates on the other were studied in presence of moisture to find out the degree of interaction of these phases, which are present in samples of sulphonitric nitrophosphate. Diammonium phosphate reacts rapidly with gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) in presence of moisture and slowly with anhydrite (CaSO_4). The corresponding reaction of monoammonium phosphate with gypsum is very slow and almost nil with anhydrite. A commercial sample of sulphonitric nitrophosphate used in the present study has been shown to contain calcium sulphate in the form of anhydrite and anhydrous dicalcium phosphate by x-ray analysis.

Nitrophosphates¹⁻³ are a group of fertilizers prepared by the reaction of rock phosphate and nitric acid, with or without sulphuric or phosphoric acid, followed by other process steps like ammoniation, granulation and drying. In the preparation of sulphonitric nitrophosphate, rock phosphate is reacted with nitric and sulphuric acids in such proportions that after the ammoniation of the reaction mass the calcium of the calcium nitrate, formed initially, is present as dicalcium phosphate and calcium sulphate. Depending upon the proportion of sulphuric acid used, the phosphate in the finished product has different degrees of water-solubility due to the presence, in varying amounts, of ammonium phosphate (mono-, di- or both) in addition to dicalcium phosphate, which is soluble in ammonium citrate but not in water. A simplified equation for the production of sulphonitric nitrophosphate containing 50 per cent of its total P_2O_5 in water-soluble form is given below:



Since the Trombay factory of the FCI Ltd. has been designed to produce 330,000 tonnes of sulphonitric nitrophosphate of the nominal grade 12.9-12.9-0 containing 50 per cent of its total phosphate in water-soluble

form⁴, it was thought desirable to carry out a detailed study on the composition of this fertilizer and the interactions of the various phases present in it. A sample of this material was received from Societe Potasse Engrais Chimique of France (PEC), who have supplied to the Trombay factory the license for their process of making sulphonitric nitrophosphate. Studies were carried out on the nature of the different phases present in the sample, their proportions and interactions between them. In this context, separate studies were also carried out with pure ingredients which have been found to be present in the sulphonitric nitrophosphates. The results are reported in this paper.

Experimental

For the determination of total P_2O_5 , water- and citrate-soluble P_2O_5 , ammoniacal and nitrate nitrogen in the nitrophosphate fertilizer, standard A.O.A.C. methods⁵ were followed. When studying the reaction rates of mono- and diammonium phosphates with different forms of calcium sulphate, the colorimetric molybdo-vanado-phosphate method⁶ was employed for phosphate estimation using a spectronic-20 colorimeter. For the estimation of calcium in presence of phosphate, precipitation of calcium oxalate was made from an acetic acid medium⁷, and then the estimation was carried out in the usual way.

The anhydrite samples used in the present study were

prepared according to the method of Powell^{8,9} described below: 5 g. of gypsum (A.R.) of B.D.H. quality was heated in a platinum dish at 600-700°C for 8 hr., cooled for some time and reheated; several cycles of this heating and cooling were repeated till the heating period was more than 120 hours.

The samples were confirmed to be anhydrite by x-ray diffraction analyses.

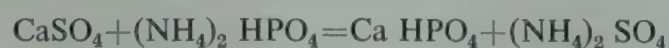
Results and Discussion

In Table 1 are given the chemical analyses of the sulphonitric nitrophosphate sample and the probable composition so far as the main ingredients are concerned.

TABLE 1—CHEMICAL ANALYSIS AND PROBABLE COMPOSITION OF SULPHONITRIC NITROPHOSPHATE

Ingredients	Per cent	Ingredients	Per cent
Total N	13.90	NH ₄ NO ₃	32.65
Ammoniacal N	8.18	CaH PO ₄	14.15
Nitrate N	5.72	NH ₄ H ₂ PO ₄	5.57
Total P ₂ O ₅	13.40	(NH ₄) ₂ H PO ₄	4.45
Water-soluble P ₂ O ₅	5.82	(NH ₄) ₂ SO ₄	4.43
Citrate-soluble P ₂ O ₅	7.40	Ca SO ₄	28.64
Citrate-insoluble P ₂ O ₅	0.18	Mg SO ₄	2.75
Total CaO	19.45	Ca F ₂	2.24
Total SO ₃	21.30	Ca ₃ (PO ₄) ₂	0.39
F	1.09		
Fe ₂ O ₃ +Al ₂ O ₃	1.18		
MgO	0.92		

It will be observed that both diammonium phosphate and calcium sulphate are present in the fertilizer. Since these two ingredients are liable to react in presence of moisture according to the equation:



With the consequent decrease in water-solubility, it was thought desirable to study the stability of the sulphonitric nitrophosphate itself in presence of moisture. 0.5 to 1 g. portions of well-ground sample (—80 mesh B.S. sieve) were kept in series of cylindrical, stoppered pyrex glass tubes with same proportion of water, namely, 1.5 g. water/g. of fertilizer at 30±0.1°C. The water-soluble P₂O₅ in the pastes was determined at different intervals of time. The results (Table 2) show that the water-soluble P₂O₅ in the fertilizer decreased very slowly and there was no further appreciable decrease after 4 days. Apparently, therefore, the reaction between ammonium phosphate and calcium sulphate does not readily take place in the commercial sample of nitrophosphate.

TABLE 2—CHANGE IN WATER-SOLUBLE P₂O₅ IN SULPHONITRIC NITROPHOSPHATE FERTILIZER BY KEEPING IT IN CONTACT WITH WATER
(1.5 g. Water/g. Fertilizer)

Nos.	Time, hr	Water-soluble P ₂ O ₅ %
1.	0	5.82
2.	4	5.78
3.	8	5.72
4.	24	5.67
5.	48	5.24
6.	72	5.02
7.	96	4.93
8.	120	4.92
9.	144	4.92
10.	168	4.90

In order to throw more light on this subject separate reactions were carried out with diammonium phosphate and with calcium sulphate dihydrate (gypsum) in presence of moisture with or without magnesium sulphate, potassium sulphate, aluminium sulphate and ammonium sulphate. Pure chemicals were used in all these experiments. Different levels of moisture were initially kept in the mixtures and water-soluble P₂O₅ was determined after drying. The results of these experiments (Table 3) show that there is an appreciable reaction between (NH₄)₂HPO₄ and gypsum in presence of moisture and that inorganic sulphates have not much effect in retarding the reaction. Even magnesium sulphate, which has been stated¹⁰ to retard such reactions was not found to have an appreciable effect. In another experiment, a mixture of dry (NH₄)₂ HPO₄ and gypsum was prepared so as to have 13.65 per cent water-soluble P₂O₅ by calculation. However, when a known weight of the sample was extracted with water and estimation was carried out by the standard method, the water-soluble P₂O₅ was found to be 5.9 per cent. Obviously, the diammonium phosphate and gypsum had reacted in the short time of water extraction involved in the analytical procedure with a reduction in water-soluble P₂O₅. In the commercial sample of the sulphonitric nitrophosphate fertilizer, however, there is little reaction between ammonium phosphate and calcium sulphate. It was thought that this might be due to calcium sulphate being present not as gypsum but in some other non-reactive form. In order to study this further, reactions between different forms of calcium sulphate, on the one hand, and mono- or diammonium phosphate or a mixture of mono- and diammonium phosphates on the other were carried out at 30±0.1°C in presence of a

TABLE 3—REACTION BETWEEN DIAMMONIUM PHOSPHATE AND GYPSUM IN PRESENCE OF DIFFERENT PROPORTIONS OF WATER AND AFTER DRYING FOR DIFFERENT INTERVALS OF TIME, WITH OR WITHOUT ADDITION OF SOLUBLE SULPHATES

Moisture in the Pastes of the Mixtures With Water, %	Time of Drying, min.	Water-soluble P ₂ O ₅ Determined by Analysis in Dried Mixtures, %				
		Mixture 1 (Calculated Water-soluble P ₂ O ₅ in the Initial Dry Mixture was 13.5%)	Mixture 2 (Calculated Water-soluble P ₂ O ₅ in the Initial Dry Mixture was 13.39%)	Mixture 3 (Calculated Water-soluble P ₂ O ₅ in the Initial Dry Mixture was 13.20%)	Mixture 4 (Calculated Water-soluble P ₂ O ₅ in the Initial Dry Mixture was 13.28%)	Mixture 5 (Calculated Water-soluble P ₂ O ₅ in the Initial Dry Mixture was 13.14%)
0	0	5.54	5.75	5.86	5.65	6.15
15	60	5.16	5.40	5.40	5.22	6.05
30	90	4.90	5.30	5.25	5.10	5.95
40	110	4.60	5.20	5.20	4.95	5.70

Mixture 1=Diammonium Phosphate and Gypsum

Mixture 2=Mixture 1+Magnesium Sulphate

Mixture 3=Mixture 1+Potassium Sulphate

Mixture 4=Mixture 1+Aluminium Sulphate

Mixture 5=Mixture 1+Ammonium Sulphate

definite proportion of water. Pure chemicals were used in all the experiments. Calcium sulphate (in different forms) and ammonium phosphates were mixed together in about the same proportion as in the commercial sample of nitrophosphate and were kept in contact with water (1.5 g. water/g. of mixture) at $30 \pm 0.1^\circ\text{C}$

in cylindrical stoppered pyrex glass tubes. The water-soluble P₂O₅ in the samples was determined after definite intervals of time. The results (Table 4), show that diammonium phosphate reacts rapidly with gypsum but its reaction with anhydrite is very slow; monoammonium phosphate, on the other hand, reacts very

TABLE 4—REACTION BETWEEN AMMONIUM PHOSPHATES AND DIFFERENT FORMS OF CALCIUM SULPHATE IN PRESENCE OF WATER AT $30 \pm 0.1^\circ\text{C}$ (1.5 g. Water/g. Mixture)

Nos.	Time of Keeping the Mixture in Contact With Moisture	Water-soluble P ₂ O ₅ Determined by Analysis, %				
		In Reactions Between Gypsum and			In Reactions Between Anhydrite and	
		Diammonium Phosphate (Initial Water-soluble P ₂ O ₅ in the Dry Mixture was 13.15% by Calculation)	Monoammonium Phosphate (Initial Water-soluble P ₂ O ₅ in the Dry Mixture was 12.02% by Calculation)	Mixture of Mono and Diammonium Phosphates (Initial Water-soluble P ₂ O ₅ in the Dry Mixture was 11.43% that due to (NH ₄) ₂ HPO ₄ being 6.73%)	Diammonium Phosphate (Initial Water-soluble P ₂ O ₅ in the Dry Mixture was 13.55% by Calculation)	Mixture of Mono and Diammonium Phosphates (Initial Water-soluble P ₂ O ₅ was 10.79% by Calculation—that due to (NH ₄) ₂ HPO ₄ being 6.06%)
1.	0 min.	5.58	11.72	6.05	13.25	8.18
2.	5 "	3.90	11.50	5.60	12.75	8.02
3.	15 "	2.80	11.25	5.38	11.25	7.90
4.	30 "	2.45	10.95	5.12	10.46	7.25
5.	60 "	1.18	10.68	4.95	8.95	6.65
6.	240 "	0.92	10.30	4.80	8.25	5.85
7.	24 hr	0.65	10.05	4.60	7.45	5.40
8.	48 "	0.32	9.75	4.45	6.85	5.27

TABLE 5—REACTION BETWEEN SULPHONITRIC NITROPHOSPHATE FERTILIZER AND ADDITIONAL QUANTITIES OF AMMONIUM PHOSPHATES IN PRESENCE OF MOISTURE AT $30 \pm 0.1^\circ\text{C}$
(1.5 g. Water/g. Fertilizer)

Nos.	Time of Keeping the Mixtures in Contact with Water	Water-soluble P_2O_5 (%) Determined by Analysis in Reactions (in Presence of Moisture) Between Sulphonitric Nitrophosphate Fertilizer and		
		Monoammonium Phosphate (Initial Water-soluble P_2O_5 in the Dry Mixture was 12.03 % by Calculation—that due to Added $\text{NH}_4\text{H}_2\text{PO}_4$ being 6.2%)	Diammonium Phosphate (Initial Water-soluble P_2O_5 in the Dry Mixture was 13.10 % by Calculation—that due to Added $(\text{NH}_4)_2\text{HPO}_4$ being 7.28%)	Mixture of Diammonium and Monoammonium Phosphates (Initial Water-soluble P_2O_5 in the Dry Mixture was 12.90 % by Calculation—that due to Added $\text{NH}_4\text{H}_2\text{PO}_4$ and Added $(\text{NH}_4)_2\text{HPO}_4$ being 2.89 and 4.19 % respectively)
1.	0 min.	11.95	12.85	11.14
2.	10 „	11.90	12.52	10.75
3.	30 „	11.85	10.80	10.40
4.	60 „	11.72	9.37	10.20
5.	120 „	11.58	7.35	9.91
6.	240 „	11.45	6.55	9.69
7.	24 hr	11.35	6.38	9.33
8.	48 „	11.30	6.02	8.45

slowly with gypsum and with anhydrite its reaction becomes almost nil. With a mixture of mono- and diammonium phosphates, the reaction with gypsum is rapid at first obviously due to the presence of diammonium phosphate, but after some time it becomes slow. With anhydrite, on the other hand, the mixture of mono- and diammonium phosphates reacts very slowly from the beginning.

These results suggested that calcium sulphate in the commercial sample of nitrophosphate might be present in the form of anhydrite. To verify this, calcium sulphate in the commercial nitrophosphate was enriched by removing ammonium nitrate, ammonium phosphates and other water-soluble components by rapid extraction with water (500 ml. of water/4 g. of sample) under suction. The residue was washed with acetone and dried in a vacuum oven at 50°C under a vacuum of 25 inches of mercury. X-ray analysis of this residue showed the presence of anhydrite (CaSO_4) and anhydrous dicalcium phosphate (CaHPO_4) as the major phases; presence of small amounts gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) was also indicated.

In order to examine the reactivity of the calcium sulphate present as anhydrite in commercial nitrophosphate, the fertilizer was allowed to react in presence of moisture with additional quantities of monoammonium phosphate, diammonium phosphate and a mixture of mono- and diammonium phosphates in separate

experiments. The results (Table 5) show that the reactivity of the calcium sulphate in the fertilizer sample is practically nil towards monoammonium phosphate and is appreciably greater towards diammonium phosphate and is of an intermediate order in the case of a mixture of mono- and diammonium phosphates. This is in line with the results given in Table 2 which show some decrease in water solubility in the commercial nitrophosphate when it is kept in contact with water, the decrease obviously occurring due to the reaction between diammonium phosphate and anhydrite present in the fertilizer.

Conclusions

The results of the present study show that diammonium phosphate reacts rapidly with $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (gypsum) in presence of moisture and slowly with CaSO_4 (anhydrite). The corresponding reaction of monoammonium phosphate with gypsum is very slow and almost nil with anhydrite. The commercial sample of sulphonitric nitrophosphate has been shown to contain calcium sulphate in the form of anhydrite. The water-soluble P_2O_5 in the fertilizer has been found to decrease, to some extent, on keeping in contact with water due to the reaction between the diammonium phosphate present in it and anhydrite.

Hence, for the stability of the sulphonitric nitrophosphate the conditions of manufacture should be such

that the calcium sulphate in it should be present in the form of anhydrite and the ammoniation should be so adjusted that the presence of diammonium phosphate is minimized so that the water-soluble phosphate in the finished product is mostly in the form of monoammonium phosphate.

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Investigations on Ammonium Bicarbonate Manufacture

Part I—Experiments on the Absorption Kinetics of Carbon Dioxide in Ammonium Carbonate Solution

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Despite progressively continued rise in ammonium bicarbonate production, little attention has been paid to the formulation of the parameters affecting carbon dioxide absorption, product drying and selection of process and equipment. In the first of a series of papers, the author discusses the results of an experimental study on operational variables on bicarbonate formation step, viz. magma temperature, ammonia and carbon dioxide concentrations in the liquid phase, carbon dioxide concentration in the gaseous phase, slurry concentration, etc.

Introduction

Ammonium bicarbonate is prepared commercially by passing gaseous carbon dioxide through an aqueous ammonia solution. The availability of both carbon dioxide and ammonium carbonate solution—the former as a by-product—from the Sindri Fertilizers factory prompted study for the design of an ammonium bicarbonate plant at Sindri.

Precise data are lacking in literature on the absorption of carbon dioxide by ammonium carbonate solution.

The data was necessary for the process design of the said plant because the formation and crystallization of the bicarbonate in the $\text{NH}_3\text{-CO}_2\text{-H}_2\text{O}$ solution start only when the CO_2/NH_3 ratio in the solution is well beyond the ammonium carbonate point.

Reaction Mechanism and Literature Survey: There is no unanimity on the mechanism of carbon dioxide absorption in $\text{NH}_3\text{-CO}_2\text{-H}_2\text{O}$ solution. Some¹ are of the view that carbonation is achieved through the formation of ammonium carbamate which later hydrolyses.

Another view is that there is first the formation of a $\text{NH}_3\text{-CO}_2$ complex which reacts further with ammonia and carbon dioxide to yield NH_4^+ and HCO_3^- ions. For the present purpose, it was felt expedient to regard the above reaction taking place in two distinct steps, viz.



The examination¹ of carbonation velocity has shown that the velocity increases with increasing ammonia concentration in the solution and increasing carbon dioxide content of the gas. A temperature increase augments or diminishes carbonation velocity at small or higher values of R respectively

$$\text{where } R = \frac{\text{mols of CO}_2 \text{ in solution}}{\text{mols of NH}_3 \text{ in solution}}$$

Ayerst² and Herbert also report that for strong solutions of ammonia, the absorption rate of carbon dioxide is a linear function of free ammonia concentration in the bulk of the solution. This applies when conversion to ammonium bicarbonate is between 10 to 100 per cent. They state that the effect of further addition of carbon dioxide after the ammonium carbonate point is obscure and is complicated by the effect of ammonium bicarbonate formation with saturation, and subsequent very rapid formation of crystals; and that the rate of addition becomes nearly constant at a slightly lower value than the rate at ammonium carbonate point.

In view of the inadequate data available, it was felt necessary to carry out investigation on the effect of such factors as temperature, ammonia concentration in the liquid phase, carbon dioxide concentration in the gas phase, presence of crystals, etc., starting from the ammonium carbonate point.

During carbonation of an ammoniated solution by batch process, the ammonia content of the solution remains constant upto the ammonium carbonate stage; but beyond this point it starts falling off owing to crystallization of ammonium bicarbonate. The progress of the reaction in the batch is followed by determining the ammonia content of the crystal-free solution.

Let $V_{\text{C.L}}$ and $V_{\text{M.L}}$ be the volumes of the carbonating liquor (C.L.) fed and the mother liquor (M.L.) after separation of ammonium bicarbonate crystals respectively in l./hr.

Let n_1 and n_2 be ammonia concentrations of C.L. and M.L. respectively in g./100 c.c.

Let X and Y be ammonium bicarbonate crystals formed and ammonia lost from the system respectively in g./hr.

Sp. gr. of ammonium bicarbonate solid = 1.586.

$$V_{\text{C.L}} = V_{\text{M.L}} + \frac{X}{1.586 \times 10^3}$$

Striking the ammonia balance,
ammonia in C.L. = ammonia in crystals + ammonia in M.L. + ammonia losses.

$$10n_1 \times V_{\text{C.L}} = X \frac{17}{79} + \left(V_{\text{C.L}} - \frac{X}{1.586 \times 10^3} \right) \times 10n_2 + Y \quad \dots (1)$$

Simplifying,

$$10 V_{\text{C.L}} (n_1 - n_2) = Y + 0.215X - 0.00631 X n_2$$

$$\text{or } X = \frac{10 V_{\text{C.L}} (n_1 - n_2) - Y}{(0.215 - 0.00631 n_2)} \quad \dots (2)$$

Since ammonia loss in exit gas did not exceed 0.1 per cent of ammonia fed into the system, Y can be neglected. Thus,

$$10n_2 \times V_{\text{M.L}} = 10 V_{\text{C.L}} n_1 - X \frac{17}{79} \text{ from eqn. (1)} \quad \dots (3)$$

Substituting for X from (2)

$$10n_2 \times V_{\text{M.L}} = 10 V_{\text{C.L}} n_1 - \frac{2.15 V_{\text{C.L}} (n_1 - n_2)}{0.215 - 0.00631 n_2}$$

Simplifying,

$$V_{\text{M.L}} = \frac{V_{\text{C.L}}}{n_2} \left(n_1 - \frac{n_1 - n_2}{1 - 0.0294 n_2} \right) \quad \dots (4)$$

Experimental Set-up and Mode of Analysis

A $\frac{1}{4}$ " jet was mounted on a cylindrical vessel with conical bottom and a cooling water jacket (Fig. 1).

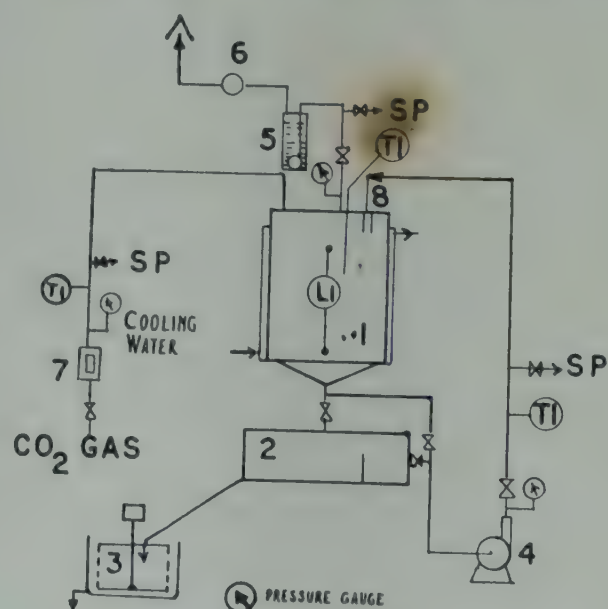


FIG. 1—Apparatus for CO_2 Absorption

1. Jacketed Absorption Vessel, 2. Closed Settling Tank,
 3. Centrifuge, 4. Circulating Pump, 5. Acid Bubbler,
 6. Wet Gas Meter, 7. CO_2 Flowmeter, 8. Convergent Nozzle.
- TI—Temperature Indicator SP—Sample Point

A settler was placed below the vessel. A clear liquor from the settler was drawn through a centrifugal pump and kept in circulation through the jet. An acid bubbler and a wet gasmeter were employed for determining the ammonia losses. The rate of carbon dioxide was found by an orifice-meter; its contents in the entering and exit gases were determined periodically by the Orsat analysis. The magma samples were analysed for ammonia and carbon dioxide contents of the clear liquor. After completion of a batch, magma was centrifuged. For carrying experiments below the reaction temperature 35°C, chilled water was employed to remove the reaction heat. Owing to practical difficulties encountered in determining mother liquor and salt quantities without incurring losses in centrifuging, it was found convenient to base material balance on ammonia analysis of the liquor and apply equations (1) to (4).

It was found in the experiments that the volume of the charge remained practically unchanged and ammonia in the unabsorbed exit gases was negligible.

It was also not possible to draw a representative magma sample for determining carbon dioxide and ammonia by titration. The only recourse left was the evaluation of material balance based on ammonia contents of crystal-free samples. The recurring analysis of the liquor for carbon dioxide was obviated by establishing a correlation between ammonia and carbon dioxide concentration in the liquor in the presence of crystals at constant temperature by experimentation. Equipped with a sparger and maintained at a constant temperature, a carbon dioxide bubbler containing $\text{NH}_3\text{-H}_2\text{O-CO}_2$ solution and salt provided an easy means of collecting this data. As carbonation proceeded samples were drawn and immediately analysed for ammonia and carbon dioxide contents in the crystal-free liquor. The results are shown in Fig. 2.

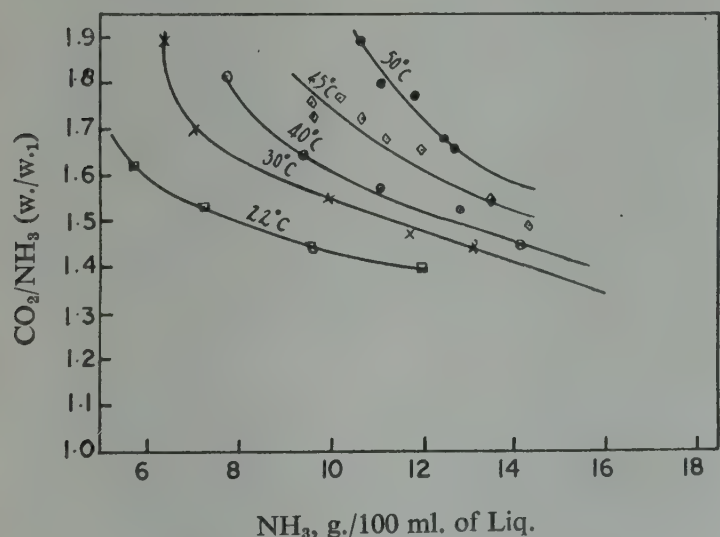


Fig. 2— CO_2/NH_3 vs. Temperature

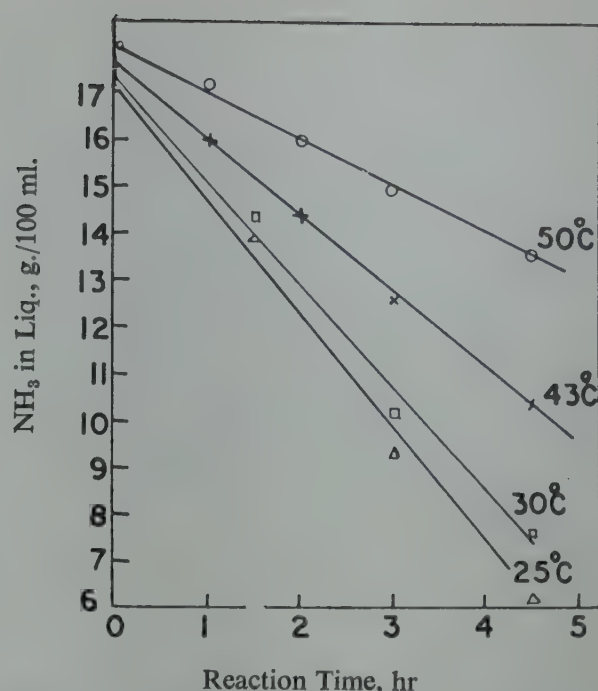


Fig. 3—Drop of NH_3 Concentration in Liquor (Batch Process)

Results and Discussion

The progress of the batch reaction can be best followed from the plot of ammonia concentration with time at constant temperature (Fig. 3). The linear drop of ammonia concentration in the liquor should not be mistaken for constant reaction rate since, owing to progressive crystallization, there is continued corresponding reduction in the liquid volume of the batch. The influence of ammonia concentration on reaction rate is however, discussed later.

Effect of Temperature: Experiments were conducted at temperatures varying from 25 to 50°C. Data (Figs. 4 & 5) show that the absorption rate decreases with rising temperature and the influence on absorption rate becomes increasingly important as the ammonia concentration in the solution drops.

The above results corroborate the observation of Ramm.¹ A possible reason for reduced reaction rate is the higher solubility of salt which raises the ratio R . Owing to the dependence of the carbon dioxide partial pressure exerted by the solution on R and temperature, the driving force of carbon dioxide for mass transfer is reduced (Figs. 2 & 6).

Carbon Dioxide and Ammonia Concentrations: The absorption rate of carbon dioxide at varying gas concentration vs. ammonia concentration at 40°C. has been plotted in Figs. (7) and (8). The results can be correlated by the expression

$$W \propto C^n, \propto 1.35 N$$

where W = CO_2 absorption rate, lb/hr

C = mol. fraction of carbon dioxide in gas phase.

N = ammonia concentration in liq., g./100 cc.

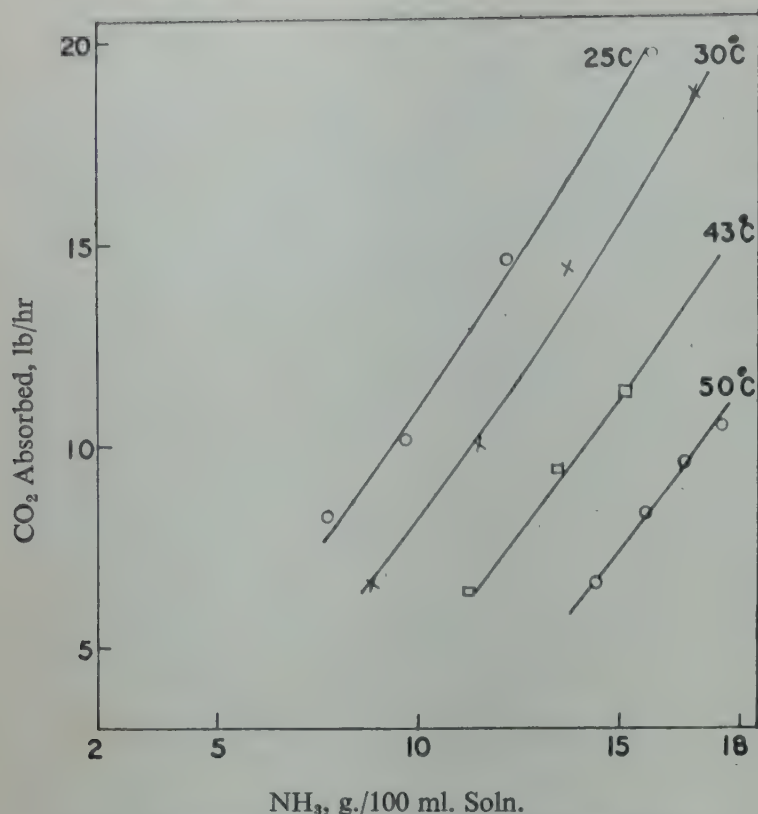


Fig. 4—Influence of Temperature and Concentration of Liquor on Absorption Rate

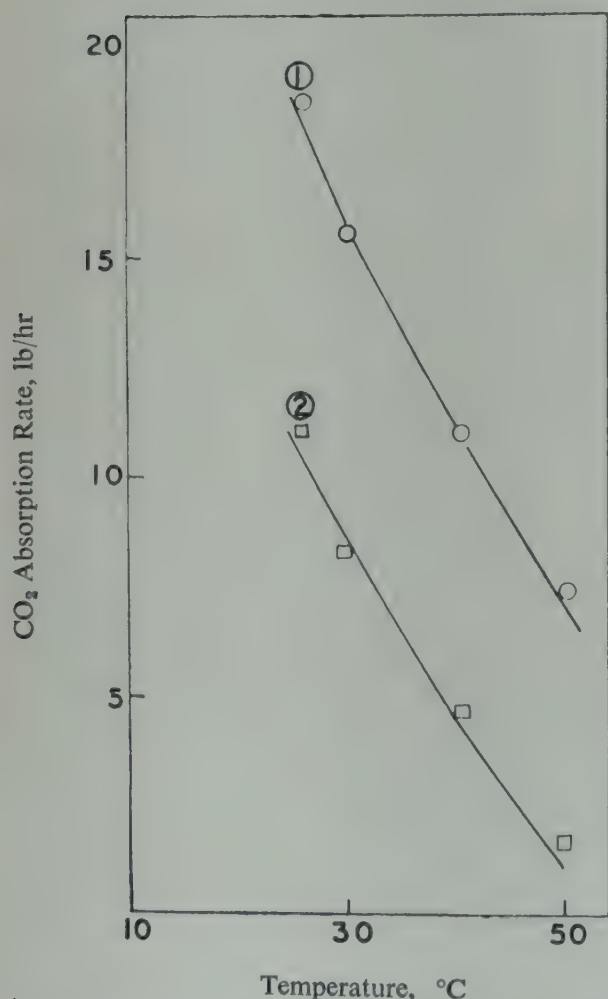


Fig. 5—CO₂ Absorption vs. Temperature at constant NH₃ Concentration
 (1) NH₃ Conc. in Liq.=15 g./100 ml.
 (2) NH₃ Conc. in Liq.=10 g./100 ml.

The exponent n is a function of ammonia concentration.

Thus, the carbonation velocity, which according to previous investigation was found to be a function of ammonia concentration in solution upto the carbonate stage, follows this trend beyond this stage as well. However, the reported observation of Ayerst and Herbert², that the carbon dioxide addition rate becomes nearly constant at a slightly lower value than the rate at ammonium carbonate point, could not be confirmed. Viewed from their conclusion of a linear relationship between absorption rate and CO₂/NH₃ ratio in solution, it is not clear why a break in this relationship should occur at the ammonium carbonate point. The CO₂/NH₃ ratio continues to rise after the ammonium carbonate point (Fig. 2), and it does seem logical to observe a drop in the absorption rate with rising CO₂/NH₃ ratio and falling ammonia strength in the solution (Figs. 4 & 7).

Because of the reduced absorption rate at lower ammonia concentration, it would not be economical to run a batch below 8 g. ammonia/100 c.c. of the solution. A continuous process should, therefore, be operated at a sufficiently high ammonia concentration commensurate with safe working atmosphere during centrifuging and drying. Because of the considerably high carbon dioxide absorption rate at high ammonia concentrations, it is profitable to split the unit into stages. Thus, for a continuous reaction vessel fed with ammonium carbonate solution of 17 g. ammonia/100 c.c. and discharging slurry containing 8 g. ammonia/100 c.c. in the liquor, 0.63 cft are needed for two stages operating at 12 and 8 g. ammonia/100 c.c. and only 0.56 cft. for three stages working at 14, 11 and 8 g./100 c.c. respectively as against one cft for one stage (Calculations based on equations 1 and 4 & Figs. 2 & 4). The pronounced influence of carbon dioxide concentration on mass transfer rate (CO₂ concentration variation from 0.83 to 0.23 mol fraction) brings to bear the importance of using a CO₂-rich gas. With carbon dioxide containing 20 per cent inerts, it is difficult to improve carbon dioxide efficiency in a single agitated unit beyond 40 per cent. Obviously indispensable for a large plant, carbon dioxide circulation system has to be designed for an optimum inert level.

Presence of Crystals: The results of four experiments are given below (Table 1). In fact, the absorption rate is slightly reduced on elimination of salt crystals and hence no useful purpose is served by including a settler in the system.

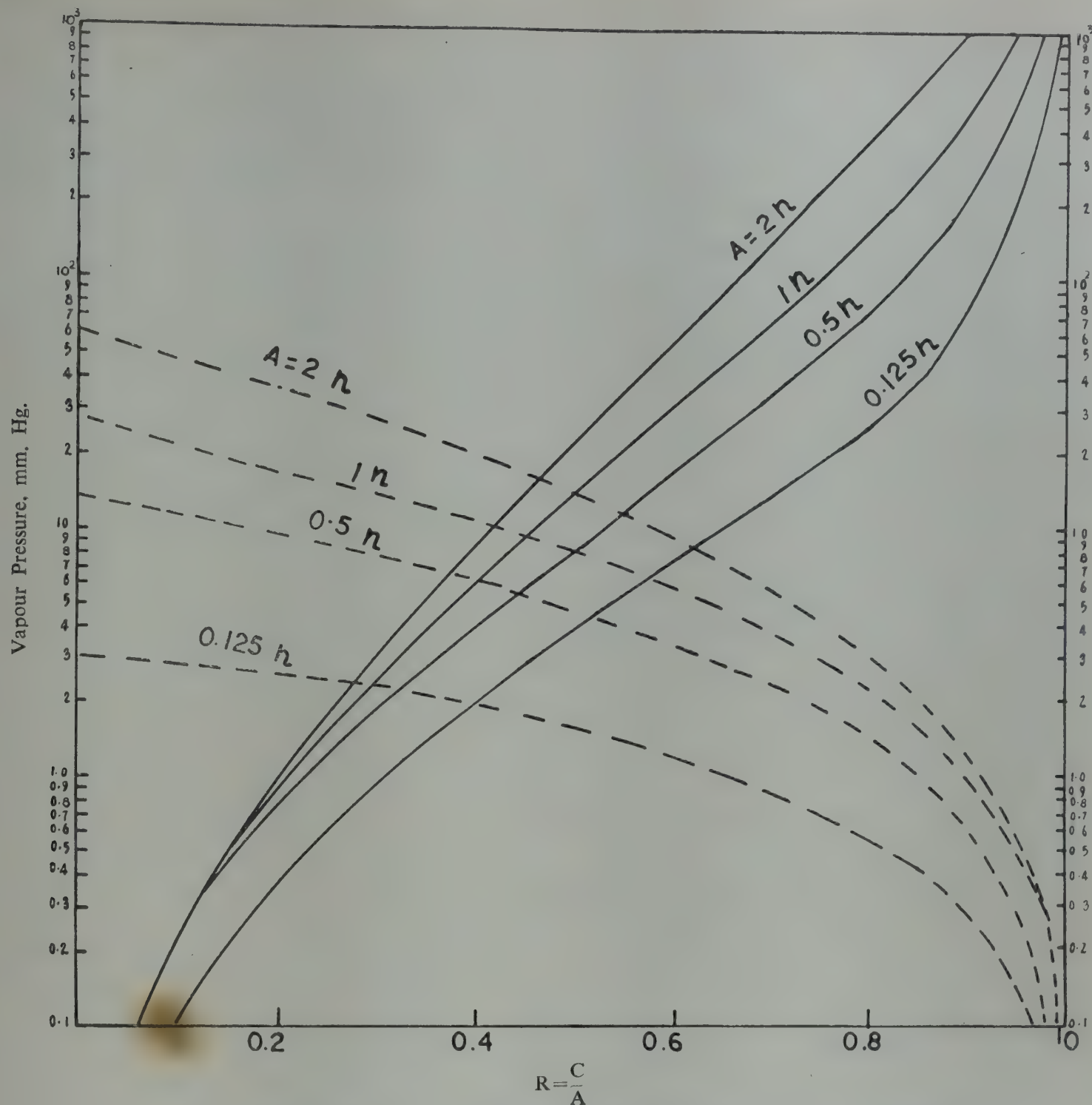


Fig. 6—Partial Pressure of CO_2 (full lines) and NH_3 (broken lines) over Aqueous Solution at 40°C .

$$R = \frac{C}{A} = \frac{\text{mol. CO}_2}{\text{mol. NH}_3}, \quad n = \text{normality of ammonia}$$

TABLE 1— CO_2 ABSORPTION AT VARYING MAGMA CONCENTRATION

Carbonate Liquor in Reaction Vessel, gals	Solids, % by vol.	Average CO_2 Concentration, mol%	Magma Temp., $^\circ\text{C}$	Ammonia drop in Soln. after 3 hr. g./100 c.c.	Yield of Crystals, lbs	Average Absorption Rate, lb/hr
20	60	76	41	7.6	98	10.6
20	60	76	41	8.1	102	11.0
20	15	77	40	6.3	88	9.6
20	15	75	40	6.6	90	9.8

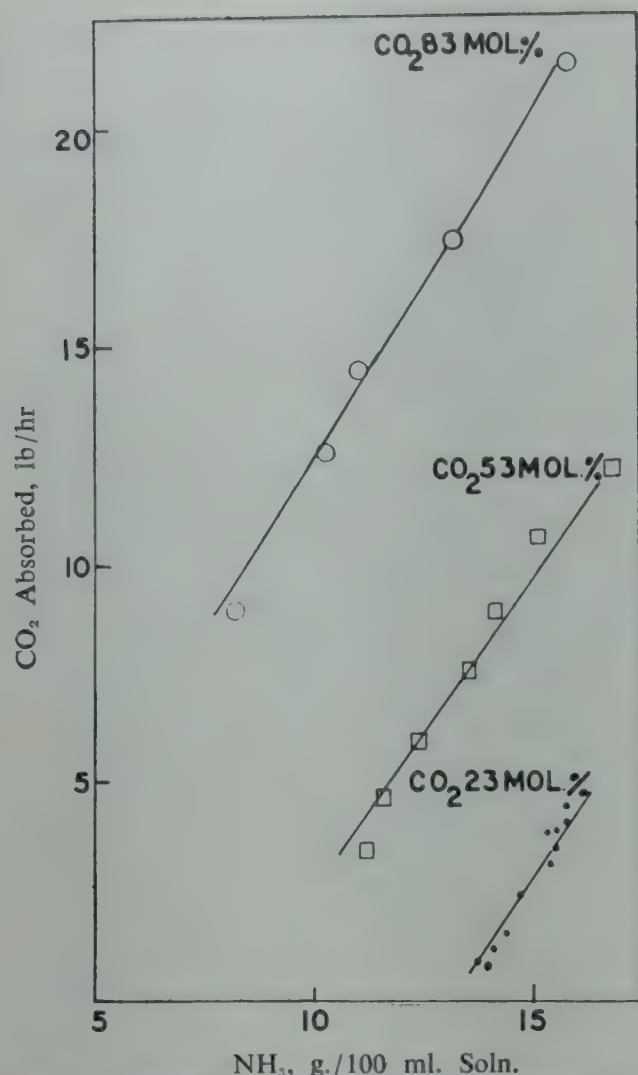


Fig. 7—Absorption Rate vs. NH_3 Concentration in Liquor at Different CO_2 Gas Concentrations

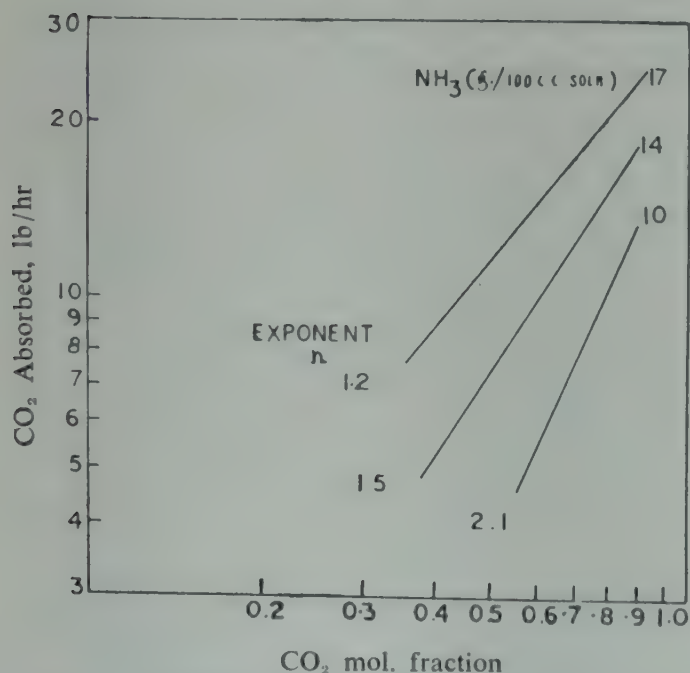


Fig. 8—Absorption Rate vs. CO_2 Gas Concentrations

Conclusions

(1) Because of the higher absorption rate with higher ammonia concentration, a continuous absorption unit using stagewise contact of carbonating liquor and carbon dioxide would have greater capacity per unit volume or power input.

(2) It is not economical to run a batch unit below 8 g. ammonia/100 c.c. and a continuous unit should be operated at high ammonia concentrations subject to the toleration limit of vapour ammonia in plant atmosphere. At 40°C ., the concentration corresponds to 9-10 g. ammonia/100 c.c.

(3) The gas used for carbonation should be rich in carbon dioxide. This is particularly significant for the final carbonation stage where ammonia strength of solution is low.

(4) The reaction temperature should be maintained preferably below 40°C . For a continuous operation unit, where the ammonia concentration level in solution is correspondingly lower vis-a-vis a batch unit the use of a chilled water unit for cooling deserves serious consideration.

Acknowledgements

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Simultaneous Spectrographic Determination of Some Minor and Trace Elements in Fertilizer Raw Materials-2: Gypsums

By

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In part I of this paper¹, a number of trace elements in some Indian limestones have been determined. In the present work some minor and trace elements, viz. copper, chromium, vanadium, manganese, barium, titanium and strontium, have been determined in five Indian gypsums, using d.c. arc. Cobalt has been used as an internal standard for these elements.

Introduction

Gypsum has many uses in the agricultural field. It is used as a raw material for production of ammonium sulphate. For correction of the alkaline soils, it is considered a good practice to apply manure or to plow under a green manuring crop in conjunction with the application of ground gypsum. One of the uses of gypsum is as a preservative for manures to decrease nitrogen losses. Dalal et al² have studied gypsum as a fertilizer also.

The gypsum used for production of fertilizer should have a high calcium sulphate percentage and a less amount of salts of other elements. The less the impurities in gypsum, the more economical and efficient will be the production of fertilizer. As regards the latter three uses of gypsum, it is added to the soil along with all the impurities present in it. The impurities will have their own effect on the metabolism of plants. The role of some micronutrients has been discussed earlier^{1,3} and also can be found in literature.

In view of the above facts it was thought useful to determine the impurities in some Indian gypsum samples. The major impurities in the sample can be determined easily by chemical method. In gypsum samples from Kavas, Jamsar and Tiruchirapally, some major impurities such as silica, ferric oxide, aluminium oxide and magnesium oxide have been chemically estimated by

Roy et. al⁴. For determination of minor and trace impurities, spectrographic method is preferred. Fabrikova and Isaeva⁵ used flame photometry for the estimation of strontium and barium in gypsum. In the present work, some minor and trace impurities, e.g. copper, chromium, vanadium, manganese, barium, titanium and strontium have been estimated by the emission spectrographic method using a d.c. arc which is most sensitive for elements present in very small quantities.

Experimental

Description of Samples: The gypsum samples studied were from (1) Dhirara (2) Jamsar (3) Kavas (4) Tiruchirapally and (5) Utterlai. The samples 1 to 3 and 5 (all from Rajasthan) were collected from the Sindri fertilizer factory while No. 4 (from Madras) was received from Neyveli*. On samples 2 to 4 some investigations had already been carried out in this laboratory.⁴

Procedure: For detection of the elements in the samples, about 50 mg. of each of oven-dried samples was mixed with 50 mg. of specpure graphite powder. About 35 mg. of the mixture was filled in specpure graphite rods in duplicate. The electrode shape, arcing

* Neyveli Lignite Corporation Ltd., Neyveli, S. Arcot, Madras

conditions and equipment are described earlier¹. The elements detected are given in Table 1.

TABLE 1—ELEMENTS DETECTED IN GYPSUM SAMPLES

Sl. No.	Source	Elements Present
1.	Dhirara (Rajasthan)	Ca, Si, Fe, Mg, Sr, Al, Ti, Na, Mn, Ba, K, V, Cr & Cu.
2.	Jamsar (Rajasthan)	Ca, Si, Al, Fe, Mg, Sr, Ti, Mn, Na, Ba, K, V, Cr, Cu & Ni.
3.	Kavas (Rajasthan)	Ca, Si, Al, Fe, Mg, Sr, Ti, Mn, Ba, Na, K, V, Cr, Cu & Ni.
4.	Tiruchirapally (Madras)	Ca, Si, Al, Fe, Mg, Sr, Ti, Na, Mn, Ba, K, V, Cr, Cu & Ni.
5.	Utterlai (Rajasthan)	Ca, Si, Al, Mg, Fe, Sr, Ti, Mn, Na, Ba, K, Cr, V & Cu.

N.B.—Amounts are roughly in decreasing order.

For estimation of minor and trace elements, 50 mg. of oven-dried samples were mixed with 50 mg. of buffer made of 1.5 per cent of specpure cobalt powder (internal standard) in specpure graphite powder. About 35 mg. of these mixtures was packed in duplicate graphite electrodes which were used as anodes for two spectral regions. For synthetic standards a base was prepared by mixing AR/GR quality of calcium sulphate (86.0), silicon dioxide (7.5), aluminium oxide (2.5), ferric oxide (1.5) and magnesium oxide (2.5) per cent respectively. The composition of the base is based on the average of the percentage of these elements in the five samples, determined semi-quantitatively⁶. The compounds of the elements—mostly oxides—to be estimated were mixed in 1 g. of the base in such a ratio that the

strongest standard (No. 1) was obtained. Standard No. 2 was made by mixing 100 mg. of No. 1 with 100 mg. of base. Similarly three more standards were made as shown in Table 2.

TABLE 2—CONCENTRATION OF ELEMENTS IN SYNTHETIC STANDARDS, %

Elements	Std. I	Std. II	Std. III	Std. IV	Std. V
Cu	0.0160	0.0080	0.0040	0.0020	0.0010
Cr	0.0080	0.0040	0.0020	0.0010	0.0005
V	0.0400	0.0200	0.0100	0.0050	0.0025
Mn	0.1600	0.0800	0.0400	0.0200	0.0100
Ba	0.0800	0.0400	0.0200	0.0100	0.0050
Ti	0.3200	0.1600	0.0800	0.0400	0.0200
Sr	0.3200	0.1600	0.0800	0.0400	0.0200

50 mg. of the above standards were mixed with 50 mg. of the buffer containing internal standard, and 35 mg. of these were filled in duplicate graphite electrodes. The spectrographic procedure, as adopted earlier³, was followed. In the present investigation instead of only one, two regions viz. 2600-3700 and 2900-4950 Å were photographed. The selected analytical lines for all the elements, except for titanium, were the same as in the earlier work¹. For analysis of titanium, the line pair Ti 3088.025 and Co 3086.770 Å was selected.

From the analytical curves drawn for each element, between logarithm of concentration of the particular element and logarithm of the ratio of microphotometric deflections for the analytical pair, the amounts of seven minor and trace elements were calculated (Table 3).

TABLE 3—TOTAL CONTENTS OF SOME ELEMENTS IN GYPSUM SAMPLES, % OVEN-DRY WEIGHT

Sl. No.	Source	Cu	Cr	V	Mn	Ba	Ti	Sr
1.	Dhirara	0.0012	0.0017	0.0072	0.0324	0.0130	0.0617	0.2570
2.	Jamsar	0.0014	0.0026	0.0056	0.0331	0.0149	0.1626	0.462**
3.	Kavas	0.0016	0.0059	0.0069	0.0407	0.0324	0.0661	0.776**
4.	Tiruchirapally	0.0017	0.0049	0.0219	0.0495	0.0427	0.0966	0.1738
5.	Utterlai	0.0014	0.0052	0.0042	0.0347	0.0214	0.0684	0.575**

** Extrapolated values

Results and Discussion

From the elements detected (Table 1), it is found that the same elements, except nickel, are present in the samples investigated. Nickel is in traces only in the samples from Jamsar, Kavas, and Tiruchirapally but could not be estimated as the spectral lines of this element were very faint for measurement on micro-photometer.

Out of the seven elements estimated, four viz. copper, vanadium, manganese and titanium were determined from the plate on which the region 2600-3700 Å was photographed, while the rest were estimated from the plate used for the region 2900-4950 Å.

It is evident from Table 3 that the minor and trace elements vary from one gypsum sample to other. The range of copper is 0.0012 in Dhirara to 0.0017 per cent in Tiruchirapally and as such not much variation is found in this case. Chromium varies from 0.0017 in Dhirara to 0.0059 per cent in Kavas gypsum. The variation for vanadium is from 0.0042 in Utterali to 0.0219 per cent in Tiruchirapally gypsum and for manganese it is from 0.0324 in Dhirara to 0.0495 per cent in Tiruchirapally sample. The range for barium is

from 0.013 in Dhirara to 0.0427 per cent in Tiruchirapally and for titanium it is from 0.0617 in Dhirara to 0.1626 per cent in Jamsar sample. As regards strontium, the variation in its contents is from 0.1738 in Tiruchirapally to 0.776 per cent in Kavas gypsum.

From the above results, it is clear that most of the estimated elements are minimum in Dhirara and maximum in the Tiruchirapally sample, with a few exceptions.

Acknowledgement

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Studies on the Relative Efficiencies of Nitrophosphates and Other Nitrogenous and Phosphatic Fertilizer Combinations

By

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In the previous experiment* it was observed that under puddled conditions *Aman* paddy (*Patnai-23*) responded equally to sulphonitric nitrophosphate (N: P_2O_5 :: 12.9:12.9; 58:42:: ammoniacal: nitrate nitrogen and 50:50:: water: citrate-soluble phosphate) and other nitrogenous and water soluble phosphatic fertilizer combinations. The present study has been undertaken to assess the relative efficiencies of carbonitric nitrophosphate (N: P_2O_5 :: 16:13; 98 per cent of the phosphate are in citrate-soluble form and have almost similar fractions of ammoniacal and nitrate nitrogen), sulphonitric nitrophosphate and various other nitrogenous and water-soluble and insoluble phosphatic fertilizer combinations in encouraging growth, development and final yield of *Aman* paddy (*Patnai-23*) under field conditions.

Completely and partially citrate-soluble and completely water-soluble phosphates, in conjunction with both ammoniacal and nitrate forms of nitrogen, behaved equally and were superior to the insoluble phosphates combined with different nitrogenous sources.

Experimental

The field procedure, adopted previously*, was followed during the present study. The experimental plot was fairly uniform in respect of fertility, slope, etc.

Ploughing was completed on the same day keeping the headland always outside the experimental area. Similarly all other field operations were completed without any break and minimum number of trained working hands were used for these operations to minimize the biological errors. Weighed quantities of fertilizers, previously analysed, were mixed thoroughly with the treatment microplots (effective area—1/946.9th acre) each of which was well separated by 'ails' and drains restricting movement of the nutrients from one plot to the other. Phosphate fraction of the carbonitric nitrophosphate was balanced by adding appropriate phosphatic sources.

After the application of the fertilizers, transplanting was completed on 8-8-65 with 5 weeks old seedlings

keeping the row-to-row and hill-to-hill spacings constant at 12 and 8 inches respectively. Attention was paid towards weeding, water level in the field, insect control, etc.

The growth and developmental data were collected at regular intervals during the entire growth period. The crop was harvested on 10-12-65.

Results and Discussion

The effects of different treatments on the growth and developmental characters were perceptible after fifteen days of transplanting. The growth characters in respect of the rate of increase in height of plants, number of tillers, etc., were studied periodically.

(i) *Effect of Different Nutrient Treatments on the Increase in Height of Plants:* The measurements of height for the different treatments at weekly intervals indicate that plants receiving 100 lbs. of N and P_2O_5 , irrespective of sources, were always taller than those receiving 50 lbs. of N & P_2O_5 (Fig. 3). Within the same level of application practically no difference was noticed within

* Dhua, S. P. and Chowdhury, B., *Technol.*, 3 (2) (1966), 78

carbonitric and sulphonitric nitrophosphates, ammonium sulphate-superphosphate, urea-superphosphate and ammonium sulphate nitrate-superphosphate (Figs. 1 & 2). These findings fully corroborate those of the previous experiments. Similar were the effects in case of ammonium sulphate-rock phosphate and urea-rock phosphate; whereas, ammonium-sulphate nitrate-rock phosphate treated plants at 50 lbs. level were taller than those of ammonium sulphate-rock phosphate and urea rock phosphate treatments, the plants receiving 100 lbs. level from above sources were practically similar in height. Control plants were slightly taller than the first level treatment of both ammonium sulphate-rock phosphate and urea-rock phosphate.

At both the levels of nutrient applications, rock phosphate in combination with different nitrogenous fertilizers produced unhealthy dwarfer plants as compared to other treatments.

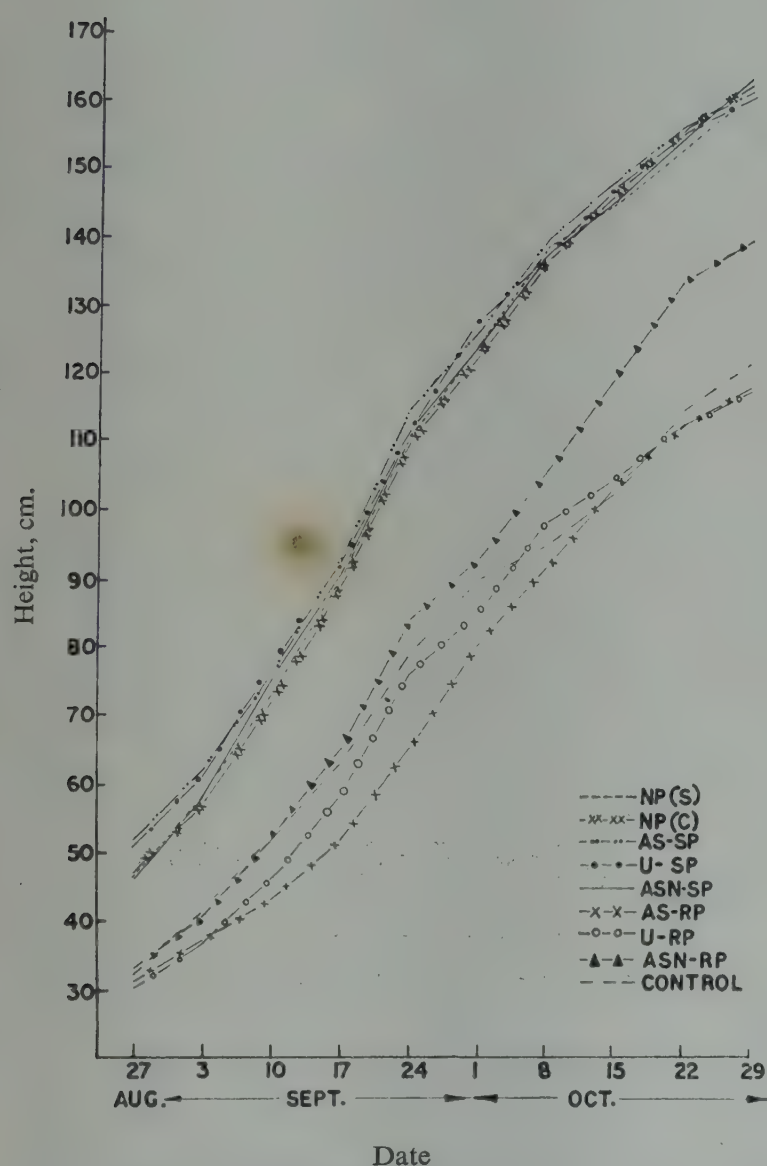


FIG. 1—Height of Plants with 50 lbs of both N and P_2O_5 /acre applied from Different Sources

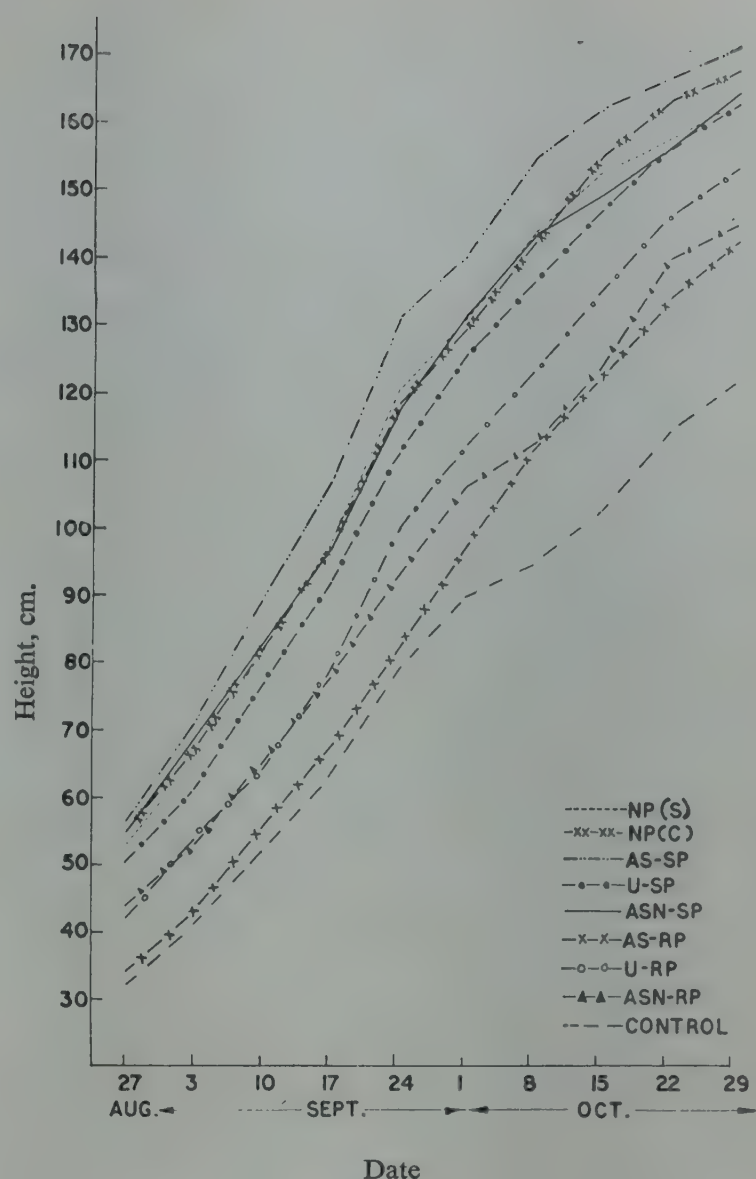


FIG. 2—Height of Plants with 100 lbs of both N and P_2O_5 /acre applied from Different Sources

Table 2 presents the rate of increase in height of plants against different fertilizer treatments at weekly intervals. It is apparent that, irrespective of nutrient sources, higher levels of both N and P_2O_5 resulted in higher rate of increase in height at the initial stage of growth. Thereafter, the rate of increase in height was almost similar under both the levels of water and citrate-soluble phosphates. After gradually attaining a maximum limit, the rate of increase in height decreased in all these cases and the differences in heights of plants under similar treatment levels became marginal. This confirmed the previous finding.

The heights of plants maintained a gradually increasing rate under higher levels of rock phosphate in combination with any of the single source of nitrogen for longer periods than under their lower level applications. The differences in heights of plants in these cases had never been close to each other except in case of ammonium

sulphate-nitrate-rock phosphate treatments where, at the later stages of growth, heights for both the levels became almost similar. The maximum rate of increase in height was generally noticed during the second and the third weeks of September indicating thereby a higher rate of physiological activities of the plants during this period which was the expected primordial stage of development of the plants. This was in agreement with the data obtained during the previous experiment. In case of rock phosphate and ammonium sulphate combinations, this peak was observed during the last week of September.

As the difference in the rate of increase in heights of plants from one month after transplanting, like the previous finding, was almost similar under different sources and levels of citrate and water-soluble phosphates in combination with both ammoniacal and nitrate forms of nitrogen it was probable that the higher level of N & P₂O₅ did not result in significantly higher rate of metabolic activities in the plants of this particular variety of paddy. Probably due to the single effects of different levels of nitrogen differential behaviour was noted in case of the rock phosphate treated plants.

(ii) *Effect of Different Nutrient Treatments on the Rate of Increase of Tillers and Rate of Tiller Death:* Table 2 shows the rate of increase in number of tillers of rice plants with different fertilizer treatments. The rate of increase followed the previous trend. During the earlier stages of growth, the rate of production of tillers was generally higher under higher levels than the lower levels of nutrients. At later stages of growth, although differences within the levels and sources could generally be recognized, little relation between

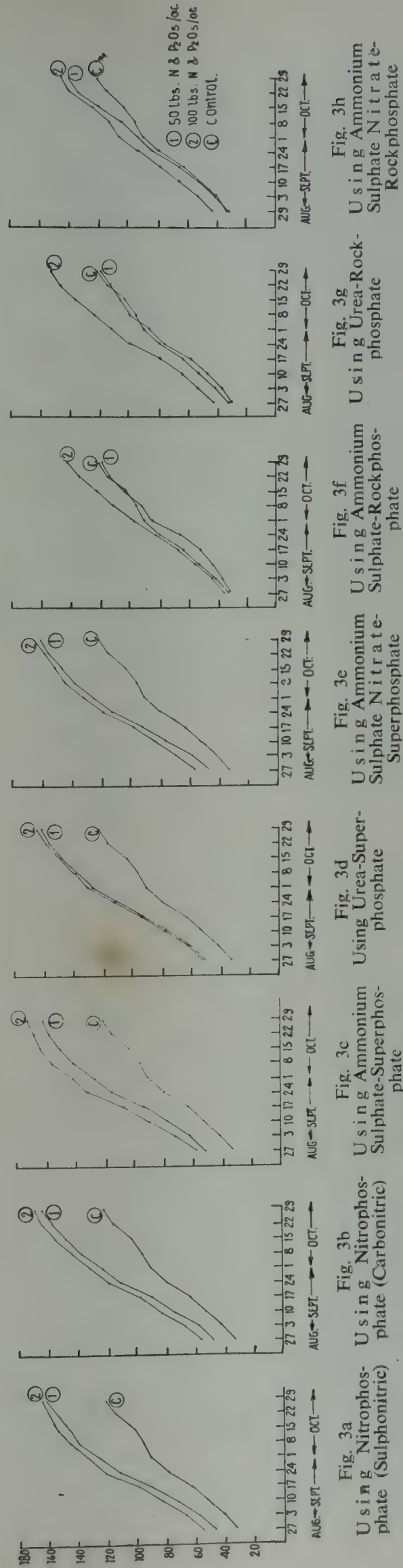
TABLE 1—ANALYSIS OF SOIL SAMPLES (OVEN-DRY BASIS)

A. Mechanical Analysis (%)	
1. Clay	28.15
2. Silt	21.12
3. Sand	45.80
	95.07
B. Chemical Analysis	
1. Organic Carbon %	1.103
2. Total Nitrogen %	0.146
3. Total P ₂ O ₅ %	0.155
4. Total K ₂ O %	0.924
5. pH	8.30
6. Base Exchange Capacity (meq./100 gm. soil)	23.952

TABLE 2—RATE OF INCREASE IN HEIGHT OF PLANTS IN CM. AND RATE OF CHANGE IN NUMBER OF TILLERS
(Average of Eight Counts)

Treatments	27.8.65 to 3-9-65		3-9-65 to 10-9-65		10-9-65 to 17-9-65		17-9-65 to 24-9-65		24-9-65 to 1-10-65		1-10-65 to 8-10-65		8-10-65 to 15-10-65		15-10-65 to 22-10-65		22-10-65 to 29-10-65	
	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller	Ht.	Tiller
NP (S)-1	11.50	1.50	15.34	1.50	16.66	3.50	21.07	3.25	13.49	2.62	14.40	-2.85	6.46	-0.87	8.91	-0.90	7.59	0
NP (S)-2	13.50	1.88	15.86	1.75	16.12	4.75	22.93	3.75	10.75	0.37	12.46	-2.62	9.14	-0.75	5.02	-1.25	5.22	-0.25
NP (C)-1	10.25	1.50	15.27	1.75	17.10	3.75	21.13	3.50	12.17	0.75	14.08	-0.38	10.52	-2.37	9.14	-0.55	6.82	0
NP (C)-2	12.58	2.13	14.80	2.25	15.87	3.25	20.75	3.50	11.95	1.25	12.80	+0.50	12.69	-3.00	8.12	-0.50	4.58	-1.40
AS-SP-1	10.00	1.50	14.53	1.25	16.99	4.25	21.42	3.50	11.83	0.12	13.58	+0.50	9.26	-1.62	7.46	-2.60	5.14	0
AS-SP-2	14.50	2.75	18.37	1.75	17.63	3.00	24.53	3.00	9.50	1.25	14.68	-2.63	7.54	-1.12	4.31	-1.50	4.47	0
U-SP-1	10.00	1.75	16.06	1.50	15.63	2.75	19.28	3.87	15.77	1.63	10.53	-0.88	9.58	-1.00	8.00	-1.77	5.01	0
U-SP-2	10.10	2.00	16.02	2.25	15.28	3.00	19.52	1.75	14.50	1.25	10.94	-2.38	11.11	-0.87	9.35	-0.30	6.24	0
ASN-SP-1	12.00	1.38	17.67	1.50	15.68	4.00	21.12	3.12	12.13	0.25	13.20	+1.28	8.20	-1.84	9.62	-0.20	5.23	0
ASN-SP-2	13.25	3.12	14.50	2.50	13.75	3.13	21.09	1.87	15.84	0.50	12.44	-0.62	5.92	-2.50	7.39	-0.63	7.84	-0.12
AS-RP-1	6.00	1.25	6.22	1.50	8.40	0.87	13.19	1.50	20.82	1.88	6.12	-1.63	11.93	-1.73	9.58	-0.27	5.15	-0.25
AS-RP-2	8.75	1.75	11.36	1.50	11.97	1.50	14.63	2.00	15.46	0.25	14.15	-1.63	10.99	-0.17	11.64	-0.58	8.53	-0.25
U-RP-1	6.53	1.25	9.64	0.75	11.83	1.62	18.12	1.88	9.25	1.37	13.27	-0.37	6.59	-1.88	7.99	-0.75	4.93	-0.27
U-RP-2	9.75	1.87	12.52	1.88	15.05	1.12	20.63	2.38	12.55	0.25	10.98	-1.88	12.57	-0.42	11.32	-0.95	6.50	0
ASN-RP-1	7.69	1.25	11.52	1.38	12.94	1.50	19.10	1.50	9.25	0.62	12.45	+1.38	14.37	-1.63	14.18	-0.75	6.00	-0.62
ASN-RP-2	9.31	1.25	12.16	1.37	13.13	1.88	14.68	2.25	13.53	0.12	6.37	+0.38	11.58	-0.75	15.96	-0.38	5.21	0
Control	9.00	1.23	11.06	1.39	10.76	1.08	16.32	0.80	10.85	0.25	4.65	+0.62	8.03	-1.00	11.89	-0.12	7.07	0

FIG. 3—Height of Plants in cm. with 50 and 100 lbs of both N and P_2O_5 /acre using different Fertilizers



the rates of increase and levels of fertilizer applications persisted. In most of the treatments maximum rate of tillering was noted between 10-9-65 and 24-9-65 almost coinciding with the peak period of increase in height of plants. This might also indicate greater physiological activities of the plants at this stage of growth.

It may also be noted that, on an average, the total number of tillers during the expected differentiation stage might indicate the total number of tillers to be retained at the flowering stage. This was true in all cases of fertilizer treatments irrespective of the maximum number of tillers (Fig. 4) observed during the last week of September and first week of October. It was not unlikely that the tillers emerging after the flower primordia formation in mother shoot proved ineffective.

Death of the tillers was noticed in most of the treatments from the first week of October. The trend of tiller death was completely inconsistent as compared to the previous growth studies. At the earlier stage, the rate of death was generally higher with sulphonitric nitrophosphate, ammonium sulphate-superphosphate, urea-superphosphate and ammonium sulphate nitrate-superphosphate treatments, while at later stages more tiller death was noticed in treatments having carbonitric nitrophosphate and rock phosphate combined with other nitrogenous fertilizers. At the approach of the flowering stage the rate became practically similar for most of the treatments and finally the number of effective tillers were counted (Fig. 5).

FIG. 4—Maximum Number of Tillers as observed with 50 and 100 lbs of N and P_2O_5 /acre applied from Different Sources

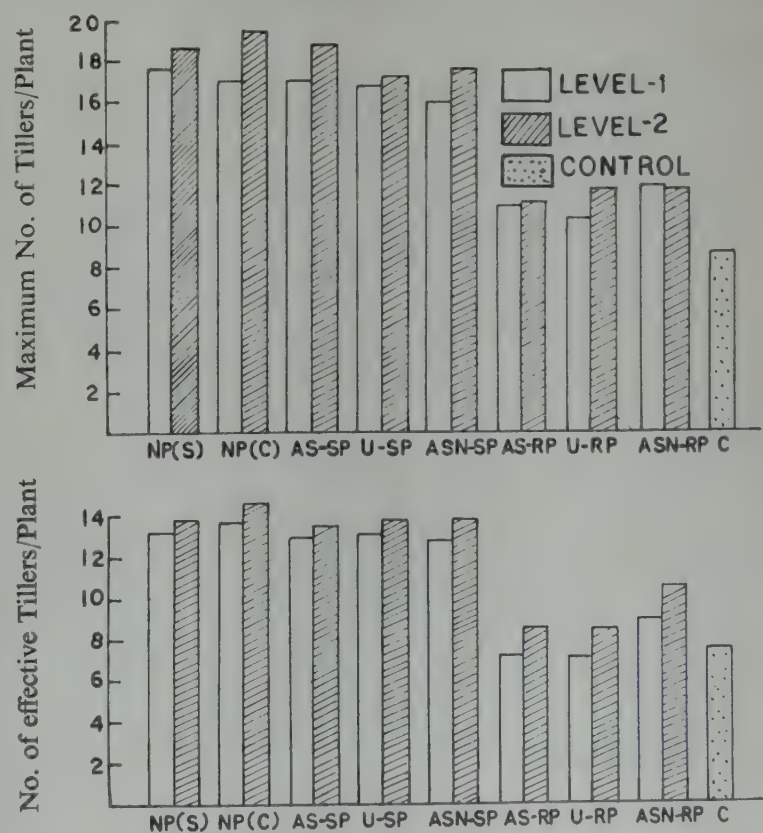


FIG. 5—Number of Effective Tillers as observed with 50 and 100 lbs of N and P_2O_5 /acre applied from Different Sources

(iii) *Effect of Different Treatments on the Length of Panicles (Table 3)*: No perceptible difference in respect of variation in panicle length due to various treatments was noted. Control plants, however, produced slightly smaller sized panicles in comparison to those from all other treatments.

The average length of panicles, therefore, in this case, might not indicate the variation in the average yield of straw and grain to be obtained from different fertilizer treatments.

(iv) *Effect of Different Treatments on Filled and Unfilled Grains (Table 3)*: Higher level applications of citrate and water-soluble phosphates with both ammoniacal and nitrate nitrogen sources produced narrower filled/unfilled grain ratios showing the production of more chaffs as against the amount of filled grains. Narrower filled/unfilled grain ratios do not, however, mean lower yields, as, in all cases, the higher yield of grain obtained from the two levels of the same treatment was always positively related with higher levels of nutrient applications which resulted in narrowing down the filled/unfilled grain ratios. The total numbers of both filled and unfilled grains in all these treatments were always higher with higher level applications than those obtained with the lower level applications of the same treatments.

The effects of rock phosphate combined with nitrogenous sources were somewhat different in this respect. Here the higher level treatments produced comparatively wider filled/unfilled grain ratios than the treatments with lower levels. Unlike above, there was hardly any

relationship between yield of grains and filled and unfilled grain ratios. The total numbers of filled and unfilled grains produced with rock phosphate and nitrogenous fertilizer combinations had little or no relationship with the levels of nutrient applied from these sources. The widest filled/unfilled grain ratio was obtained from the control plants.

(v) *Effect of Different Nutrient Treatments on 1,000 Grain Weight*: The single grain weights, as revealed by the test weights of 1000 grains, were found to be almost equal under both the levels. In some cases, however, slightly higher values were obtained under higher levels of nutrient applications.

(vi) *Effects of Different Nutrient Treatments on the Yield of Rice Grains (Fig. 6)*: The yield data obtained was of the order of the previous yield data. Statistical interpretation of the grain yields of paddy at the 5 per cent level of significance is as follows:

NP(C)₂, NP(C)₁, NP(S)₂, ASN-SP₂, U-SP₂, AS-SP₂,

USP₁, NP(S)₁, AS-SP₁, ASN-SP₁, ASN-RP₂, ASN-RP₁,

URP₂, AS-RP₂, Control, AS-RP₁, U-RP₁

TABLE 3—AVERAGE NUMBER OF EFFECTIVE TILLERS, LENGTH OF PANICLE, FILLED AND UNFILLED GRAINS, RATIOS OF FILLED AND UNFILLED GRAINS AND 1000 GRAIN WEIGHT

Treatments	Average Length of Panicle, cm.	Average Number of Grains/Panicle		Filled/Unfilled Grain Ratio	1000 Grain Weight, g.
		Filled	Unfilled		
NP (S)-1	21.25	73.95	25.70	2.87	27.70
NP (S)-2	20.75	80.03	30.70	2.60	28.00
NP (C)-1	21.26	82.06	20.00	4.10	28.20
NP (C)-2	20.73	89.42	27.20	3.28	28.20
AS-SP-1	21.24	72.52	23.38	3.10	27.55
AS-SP-2	20.76	76.95	29.24	2.63	28.10
U-SP-1	22.02	78.45	23.82	3.29	27.50
U-SP-2	21.64	79.16	29.10	2.72	27.60
ASN-SP-1	20.66	72.67	21.80	3.33	27.60
ASN-SP-2	20.65	80.90	28.37	2.85	27.75
AS-RP-1	20.41	79.32	20.62	3.84	27.90
AS-RP-2	20.60	78.17	17.62	4.43	27.90
U-RP-1	21.95	76.31	25.21	3.02	27.75
U-RP-2	21.53	87.55	21.80	4.01	27.80
ASN-RP-1	21.30	86.05	23.27	3.69	27.90
ASN-RP-2	20.88	80.07	20.00	4.00	28.00
Control	19.94	76.95	17.12	4.49	27.60

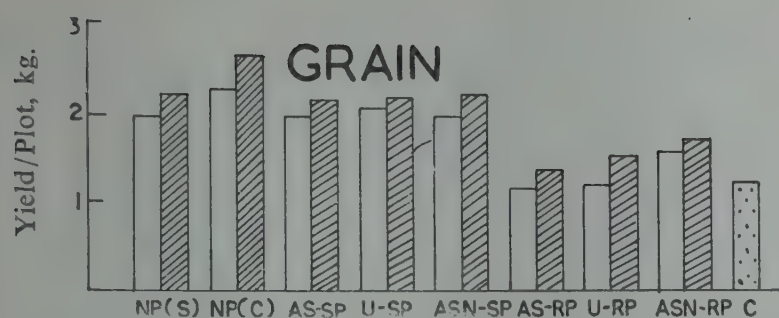


FIG. 6—Yield of Grains with 50 and 100 lbs of both N and P₂O₅/acre applied from Different Sources

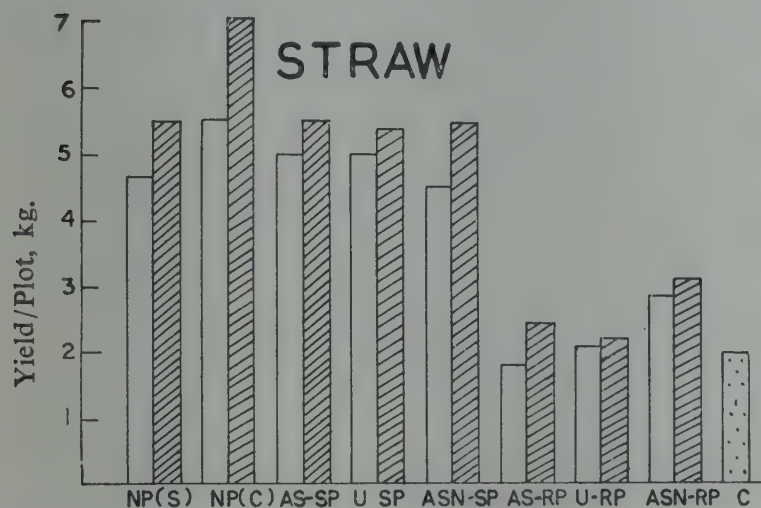


FIG. 7—Yield of Straw with 50 and 100 lbs of N and P₂O₅ applied from Different Sources

It is quite apparent from above that at the 5 per cent level of significance, there was no difference in grain yields within the treatments:

(a) NP (C)₂, NP (C)₁, NP (S)₂, NP (S)₁, U-SP₁, U-SP₂, ASN-SP₁, ASN-SP₂, AS-SP₁ and AS-SP₂ signifying that citrate and water-soluble phosphates in combination with ammoniacal and nitrate forms of nitrogen, irrespective of levels of applications of N & P₂O₅, might behave similarly in boosting up grain yields of wet land paddy.

(b) NP (C)₁, NP (S)₂, NP (S)₁, U-SP₂, U-SP₁, AS-SP₂, AS-SP₁, ASN-SP₂, ASN-SP₁, and ASN-RP₂, confirming the previous finding,* save the effects of carbonitric nitrophosphate and ammonium sulphate nitrate-rock phosphate treatments which had newly been included in this trial.

(c) NP (S)₂, NP (S)₁, U-SP₂, U-SP₁, AS-SP₂, AS-SP₁, ASN-SP₂, ASN-SP₁, ASN-RP₂, ASN-RP₁, and U-RP₂ indicating that for all levels of applications barring carbonitric nitrophosphate, partially citrate-soluble phosphates and water-soluble phosphates in combination with ammoniacal and nitrate forms of nitrogen, were at par with both levels of ammonium sulphate nitrate-rock phosphate and higher level of urea-rock phosphate combinations.

(d) U-SP₁, NP (S)₁, AS-SP₁, ASN-SP₁, ASN-RP₂, ASN-RP₁, U-RP₂ and AS-RP₂ indicating that the first level applications of superphosphate combined with different nitrogenous fertilizers and sulphonitric nitrophosphate failed to result in any difference in yield as compared to the second level application of rock phosphate along with different nitrogenous fertilizers and first level application of rock phosphate and ammonium sulphate nitrate.

(e) ASN-RP₂, ASN-RP₁, U-RP₂, U-RP₁, AS-RP₂, control and AS-RP₁ indicating that the application of rock phosphate in combination with different nitrogenous sources might not have any positive and significant response over control.

(vii) *Effect of Fertilizers on the yield of Straw (Fig. 7):* Statistical analysis of the rice straw yield data which followed the previous trend*, (Table 6) is shown below:

NP (C)₂, NP (C)₁, NP (S)₂, AS-SP₂, ASN-SP₂, U-SP₂,
 U-SP₁, AS-SP₁, NP (S)₁, ASN-SP₁, ASN-RP₂, ASN-RP₁,
 AS-RP₂, U-RP₂, U-RP₁, Control, AS-RP₁.

It indicates that at 5 per cent level of significance the second level application of carbonitric nitrophosphate produced significantly higher straw yields than all other treatments. Straw yields obtained from first level applications of carbonitric nitrophosphate, sulphonitric nitrophosphate, urea-superphosphate, ammonium sulphate-superphosphate and ammonium sulphate nitrate-superphosphate and second level applications of sulphonitric nitrophosphate, ammonium sulphate-superphosphate, urea-superphosphate and ammonium sulphate nitrate-superphosphate were similar at the 5 per cent level of significance but were superior to all the combinations of rock phosphate and various nitrogenous fertilizers at both the levels and also to control, while the later treatments and control were similar in their effects on the straw yields of paddy.

(viii) *Effects of Different Treatments on the Straw/Grain Ratio (Table 4):* Barring a few treatments with rock phosphate, all others produced wider straw and grain ratios over control. In case of all the treatments receiving water and citrate-soluble phosphates combined with various nitrogenous fertilizers this ratio was always wider than those having rock phosphate along with different nitrogenous fertilizers. Higher levels of water and citrate-soluble phosphates, in combination with ammoniacal and nitrate forms of nitrogen, always produced slightly wider ratios than all the lower level applications of these compounds. These ratios were

TABLE 4—YIELD OF RICE GRAIN AND STRAW AND STRAW/
GRAIN RATIO

(Each figure represents an average of two replicates.)

	Grain, Kg/plot	Straw, Kg/plot	Straw/Grain Ratio
NP (S)-1	1.95	4.70	2.41
NP (S)-2	2.20	5.50	2.50
NP (C)-1	2.27	5.52	2.43
NP (C)-2	2.65	7.15	2.70
AS-SP-1	1.95	5.00	2.56
AS-SP-2	2.15	5.50	2.56
U-SP-1	2.05	5.02	2.45
U-SP-2	2.17	5.42	2.50
ASN-SP-1	1.95	4.55	2.33
ASN-SP-2	2.20	5.45	2.48
AS-RP-1	1.15	1.82	1.58
AS-RP-2	1.35	2.45	1.81
U-RP-1	1.07	2.10	1.96
U-RP-2	1.51	2.22	1.47
ASN-RP-1	1.55	2.85	1.84
ASN-RP-2	1.70	3.15	1.85
Cont.	1.20	2.00	1.66
'F' Value of the treatments	3.842 **	13.377 ***	
C.D. at the 5% level of significance	0.695	1.348	

more or less erratic under both the levels of rock phosphate-nitrogenous fertilizer combinations.

(ix) *Effect of Different Nutrients on the Percentage of Nitrogen in Rice Grains (Table 5):* The nitrogen uptake was almost similar to that under the previous experiment*. A statistical analysis of the data (given below) shows

NP (C)₂, NP (C)₁, ASN-SP₂, NP (S)₂, U-SP₂, U-SP₁,

AS-SP₂, NP (S)₁, AS-SP₁, ASN-RP₂, U-RP₂, ASN-RP₁,

AS-RP₂, AS-RP₁, U-RP₁, Control.

that there was no difference in the p.c. value of the nitrogen within the following treatments:

(a) NP (C)₂, NP (C)₁, ASN-SP₁, NP (S)₂, USP₂, USP₁, ASSP₂, NP (S)₁, ASN-SP₁ and ASSP₁ indicating that citrate and water-soluble phosphates in combination with nitrate and ammoniacal forms of nitrogen had no differential effect on the percentage of nitrogen in rice grains.

(b) USP₁, ASSP₂, NP (S)₁, ASN-SP₁, ASSP₁ and ASN-RP₂

TABLE 5—PRESENCE OF NITROGEN, PHOSPHORUS AND POTASH IN RICE GRAIN & STRAW, AVERAGE %

Treatment	Nitrogen, Phosphorus & Potash in Grain			Nitrogen, Phosphorus & Potash in Straw		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
NP (S) ₁	0.781	0.669	0.756	0.694	0.152	1.587
NP (S) ₂	0.802	0.696	0.780	0.781	0.170	1.687
NP (C) ₁	0.809	0.700	0.796	0.734	0.152	1.650
NP (C) ₂	0.823	0.713	0.865	0.813	0.197	1.812
ASSP ₁	0.780	0.676	0.733	0.753	0.142	1.562
ASSP ₂	0.781	0.681	0.769	0.803	0.176	1.687
USP ₁	0.793	0.676	0.744	0.728	0.152	1.587
USP ₂	0.801	0.685	0.766	0.775	0.190	1.787
ASN-SP ₁	0.780	0.664	0.732	0.709	0.157	1.600
ASN-SP ₂	0.803	0.685	0.773	0.791	0.180	1.650
AS-RP ₁	0.687	0.509	0.526	0.800	0.162	1.512
AS-RP ₂	0.729	0.539	0.688	0.856	0.160	1.525
U-RP ₁	0.680	0.493	0.488	0.825	0.180	1.462
U-RP ₂	0.743	0.544	0.694	0.875	0.157	1.562
ASN-RP ₁	0.729	0.544	0.670	0.772	0.170	1.500
ASN-RP ₂	0.745	0.626	0.732	0.803	0.160	1.550
Cont.	0.671	0.524	0.607	0.634	0.102	1.462
'F' Value of the Treatment	6.66***	24.600***	—	—	—	—
C.D. at the 5% level of significance	0.050	0.050	—	—	—	—

(c) ASSP₂, NP (S)₁, ASNSP₁, ASSP₁, ASNRP₂ and URP₂ denoting the similar effects of the second level treatments of rock phosphate with the first level treatments of water-soluble and partially water-soluble phosphates in combination with different sources of ammoniacal and nitrate nitrogen.

(d) ASNRP₂, URP₂, ASNRP₁ and ASRP₂ showing similar effect of the first level application of ammonium sulphate nitrate-rock phosphate with the second level applications of rock phosphate with other nitrogenous fertilizers.

(e) ASNRP₁, ASRP₂, ASRP₁ and URP₁

(f) ASRP₁, URP₁ and Control

From the results of the chemical analysis, it appeared that the water and citrate-soluble phosphate fractions were similar in their effects on the quality of grain as indicated by its nitrogen content.

(x) *Effect of Different Nutrients on the Percentage of Phosphorus in Rice Grains*: As in the previous study the higher percentages of phosphorus in grains (Table 5) were generally related with the water soluble and citrate soluble phosphorus fertilization. The following observations may be made from the statistical analysis of the data (given below) on the percentage of phosphorus in rice grains:

NP (C)₂, NP (C)₁, NP (S)₂, USP₂, ASNSP₂, ASSP₂,

USP₁, ASSP₁, NP (S)₁, ASNSP₁, ASNRP₂, URP₂,

ASNRP₁, ASRP₂, Control, ASRP₁, URP₁

(a) There was no difference in respect of the percentage values of phosphorus in the rice grains due to citrate and water soluble phosphate treatments in combination with ammoniacal and nitrate forms of nitrogen.

(b) Ammonium sulphate nitrate-rock phosphate at the second level applications produced similar response in this respect, as obtained from first level application of sulphonitric nitrophosphate and urea, ammonium sulphate and ammonium sulphate-nitrate in combination with superphosphate.

(c) The first level application of rock phosphate in combination with ammonium sulphate and ammonium sulphate-nitrate and second level applications of rock phosphate in combination with urea and ammonium sulphate were similar in effect as obtained from control.

(d) Urea and ammonium sulphate, in combination with rock phosphate at the first level and ammonium sulphate-rock phosphate at second level, were similar in their effects and were at par with the control.

(xi) *Effect of Different Nutrients on the Percentage of Potash in Rice Grains*: Chemical analysis of rice grains for the percentage of potash indicates clearly that on an average higher percentage of potash in grains was found in those treatments having higher percentage analysis for nitrogen and phosphorus. This also indicates that potash is not a limiting factor in this soil and a greater amount of potash is taken up along with nitrogen and phosphorus to produce higher yields.

(xii) *Effect of Different Nutrients on the Percentage of Nitrogen in Rice Straw (Table 5)*: Like previous year, a higher percentage of nitrogen in rice straw was noted with the treatments receiving higher levels of both the nutrients, nitrogen and phosphorus, as carbonitric and sulphonitric nitrophosphates and different nitrogenous sources combined with superphosphate. Percentage values for nitrogen in rice straw obtained from the rock phosphate-nitrogen treatments were generally higher than those obtained from nitrophosphates and various sources of nitrogen in conjunction with superphosphate. This is probably due to the fact that rock phosphate supplied limited quantity of phosphorus resulting in higher accumulation of non-protein nitrogenous compounds in the straw rather than the formation of proteins. Consequently, this physiological unbalance lowered straw yields and increased the percentage value for nitrogen in straw. Nitrogen values of the control plants were the lowest.

(xiii) *Effect of Different Nutrients on the Percentage of Phosphorus in Rice Straw*: Data presented in Table 5 indicate that the lower applications of nitrophosphates and straight nitrogenous and phosphatic sources resulted in lower percentages of phosphate in rice straw, than the higher levels of applications. Similar observations were recorded during the previous study.

Higher level applications of rock phosphate in conjunction with nitrogenous sources produced slightly lower percentage values for phosphorus than the lower level applications. It is likely that availability of phosphate from the higher level of rock phosphate applications was more resulting in more absorption and translocation of phosphorus from the vegetative body to the seeds. This, consequently, led to comparatively higher yields of straw and grains and lower percentage of phosphorus in the straw as compared to the lower levels.

Again, rock phosphate being insoluble was, perhaps, unavailable to the plants during the earlier stage of growth. A portion of it might have become soluble due to complex reactions prevailing under water-logged condition in the rhizosphere and as such absorbed by the plants during the later stages. The absorption of phosphate in the later stages might have encouraged accumulation of it in the culm and was not translocated to the grains, a fact which is evident from the corresponding lower percentage of phosphorus in the grains, resulting in very close percentage value for phosphorus as obtained under water soluble, citrate soluble and partially citrate soluble phosphate treatments.

(xiv) *Effect of Different Nutrient Treatments on the Percentage of Potash in Rice Straw:* The percentage of potash in the culm, as indicated in Table 5, clearly shows that the higher percentage values for potash maintained a relation with the yield and the percentage of nitrogen and phosphorus in rice straw.

Summary

The water and citrate-soluble phosphates, in combination with ammoniacal and nitrate nitrogen, increased plant heights significantly over the rock phosphate-nitrogen treatments and the control, but showed no difference between themselves under the same level of application. The rates of increase in heights, having its peak at the primordial stage of development of plants, were initially higher under higher nutrient levels, but became similar under all the treatments at the later stages of growth.

Under higher levels of fertilizer treatments the number of effective tillers per plant was more. The rate of increase in number of tillers was also higher at the earlier stages of growth under higher fertilizer levels, but was similar under both the levels at later stages. The rate of tiller death was found highest at the earlier stages of growth of the plants receiving water-soluble and partially water-soluble phosphatics. In citrate-

soluble and insoluble phosphate treatments, however, the highest rate of tiller death occurred at the later periods. In all cases and under all the treatments the number of tillers per plant around the primordial stage generally indicated the number of effective tillers to be produced. No appreciable difference in the lengths of panicles and test weight of 1000 grains was noted under the two levels of fertilizer treatments from different sources.

Citrate and water-soluble phosphates at higher levels produced narrower filled/unfilled grain ratios, while rock phosphate produced the reverse effect.

As regards yields of grain and straw, no difference was observed between citrate and water-soluble phosphates which, irrespective of nitrogen sources, produced much higher yield over the rock phosphate and control treatments. The yield of straw was highest under the second level application of carbonitric nitrophosphate. The phosphate sources were found to affect the straw: grain ratio which became wider under citrate and water soluble phosphatic fertilizer treatments. Nitrate or ammoniacal forms of nitrogen and water or citrate soluble phosphate did not apparently affect the nitrogen percentages of grain and straw.

Under rock phosphate treatment the percentage of phosphate in grain was generally lower and in straw was generally higher than under water and citrate soluble treatments.

Potassium percentages in both grain and straw were found to be directly associated with the respective percentages of nitrogen and phosphate.

Acknowledgements

The authors' thanks are due to Dr. K. R. Chakravorty, General Manager, and Sri A. K. Roy, Additional Superintendent, P & D Division, for their keen interest in this work. Thanks are also due to Sri B. P. Roy for his sincere help at different stages.

Corrosion in an Air Liquefaction Plant: A Case History

By

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Leaks were detected during pneumatic testing in various sections of the air liquefaction plant of the Trombay fertilizer factory. Detailed investigation showed that these were due to the transgranular cracking caused by the presence of chloride and residual stresses.

During the pneumatic testing in the air liquefaction plant at Trombay, leaks in the stainless steel vessels were detected in the different sections (Table 1) of the air fractionation unit. Except for reversing exchangers, the material of construction in all the cases was AISI 304 stainless steel. The composition of different heats are given in Table 2. Most of the leaks were detected in the vicinity of welds, say within 2 inches, except one crack which was about 3 inches away from the weld.

Detailed investigation was carried out with the north side high pressure column; in all, 44 leaks were observed on the five double seam weldings with the backing rings and the seven single seam weldings. The total seam portions done with the backing rings had a width of 2.25 inches on the inside surface of the vessels and 0.5 inch on the outside; the ring was welded with 3/16" plate.

TABLE 1

Description of the Units	Number of Leaks	
	North Side Unit	South Side Unit
1. High Pressure Column	44	51
2. Low Pressure Column	5	1
3. Crude Argon Column	no leaks	5
4. Nitrogen Exchanger	2	no leaks
5. Nitrogen Sub-cooler	no leaks	no leaks
6. Liquid Sub-cooler	"	"
7. Rich Liquid Filters	"	"
8. Expansion Engine Oil Filters	"	"
9. Oxygen Exchanger	"	"
10. Reversing Exchanger (Aluminium)	"	"
11. Clapet Boxes	"	"

TABLE 2—COMPOSITION OF THE VARIOUS HEATS OF AISI 304 STAINLESS STEEL

Heat	Composition, % by wt.								
	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
1.	0.053	1.02	0.02	0.014	0.56	9.35	18.51	0.16	0.17
2.	0.045	1.65	0.023	0.012	0.64	9.21	18.29	0.37	0.32
3.	0.058	1.87	0.023	0.009	0.45	9.10	18.36	—	—
4.	0.052	1.74	0.026	0.012	0.50	9.02	18.38	—	—
5.	0.063	—	—	—	—	9.20	18.58	—	—
6.	0.066	—	—	—	—	9.20	18.49	—	—
7.	0.079	—	—	—	—	8.76	18.49	—	—

An inspection of the inside of the vessel showed extensive bluish white deposits on the sieve plates—and also along the circumference—made of copper which were fitted to the cylindrical column. Bluish white deposits were also observed on the inside surface of stainless steel shell where sieve plates were fitted to the column. On chemical examination, the deposits were found to be a mixture of copper chloride and free copper containing about 16 per cent chlorine.

To determine the exact nature and cause of the leaks, metallographic examinations of samples cut out from different portions—failed as well as undamaged—were taken. In each case, the top outside surface was polished, etched and viewed under the microscope (Photos 1-9). The following samples were taken for examination: (i) Shell edge near the welding; (ii) top backing ring; (iii) longitudinal single weld with shell plate; (iv) shell plate by the side of the weld on backing ring (double weld); and (v) weld on backing ring.

Observations

(1) *Shell Edge near the Welding*: Two samples, one undamaged and the other damaged, were examined where the leak had actually occurred. Both have identical structure, austenitic with pinholes. There is absence of sigma phase but carbide segregation has been observed and the grains appear to be plastically strained. The damaged sample showed transgranular cracking of highly branched nature (Photo 1). The carbide segregation is prominent along the cracks.

(2) *Top Backing Ring (Photo 2)*: This portion was reported to be undamaged and no leaks were reported in this part of the column. The structure is the same as



Photo 1

304 Stainless Steel Damaged Shell Edge Near the Welding ($\times 200$).

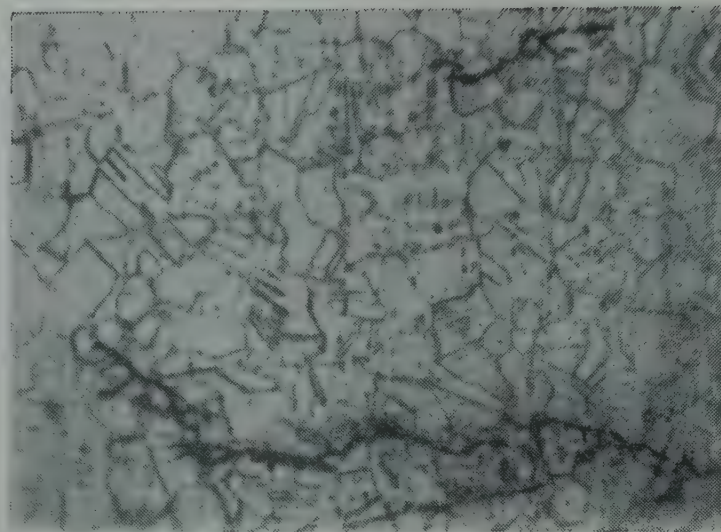


Photo 2

304 Stainless Steel Top Backing Ring Apparently Undamaged ($\times 115$).

that in sample 1 except that the cracking pattern is not so much of a branched nature as given in Photo 1.

(3) *Longitudinal Weld with Shell Plate (single weld)*: From this, the following three samples were cut out: (a) *Weld metal* (Photo 3): Its structure is dendritic with some ferrite; interdendritic segregation of carbide has been observed; (b) *Shell plate adjacent to the weld metal* (Photo 4): Its structure is austenitic with pinholes; there is absence of sigma phase but carbide segregation has occurred, and the grains appear plastically strained; and (c) *Shell plate away from the weld metal*: The structure is quite identical to that in Photo 4.

(4) *Shell Plate by the Side of the Weld on Backing Ring (double weld)* (Photo 5): The structure is austenitic with pinholes. There is absence of sigma phase but carbide segregation has occurred and the grains are plastically strained.

(5) *Weld on Backing Ring*: Two samples, one from the undamaged and the other from the damaged portion, were examined. The structures were the same except that the damaged sample showed cracks. The following different zones of damaged sample were examined: (a) *Weld zone* (Photo 6): The structure is dendritic with interdendritic segregation of carbide. A highly branched cracking pattern is observed along the dendrites; (b) *Juncture of weld metal and backing ring* (Photo 7): The figure shows only the weld metal in etched condition while the backing ring is unetched. The crack apparently proceeds from the big crack in the weld zone to the parent material. In addition to the one big crack, there are several small cracks in the weld metal which after passing along the dendrites pass on to the backing ring parent metal. The cracking pattern is of a

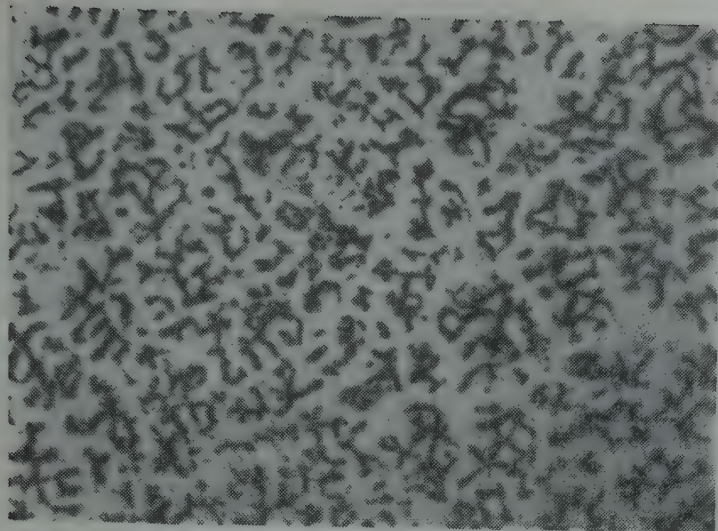


Photo 3
Longitudinal Weld ($\times 340$).

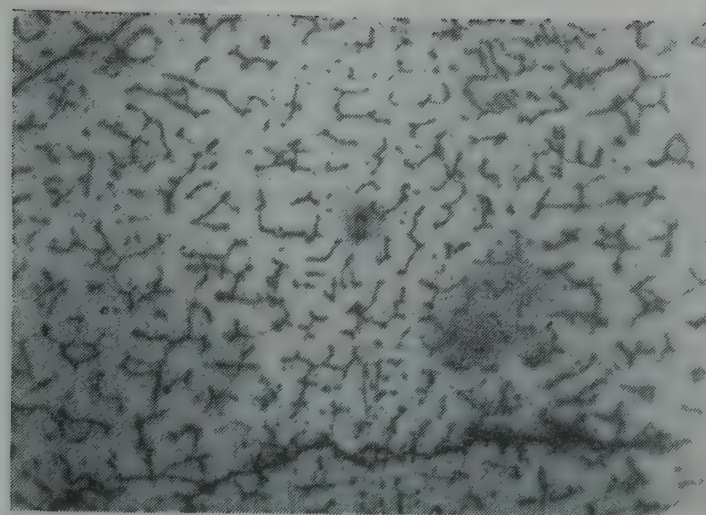


Photo 6
Weld Metal (Double Weld) On the Backing Ring ($\times 450$).



Photo 4
304 Stainless Steel Shell Plate Adjacent to the Longitudinal Weld ($\times 200$).

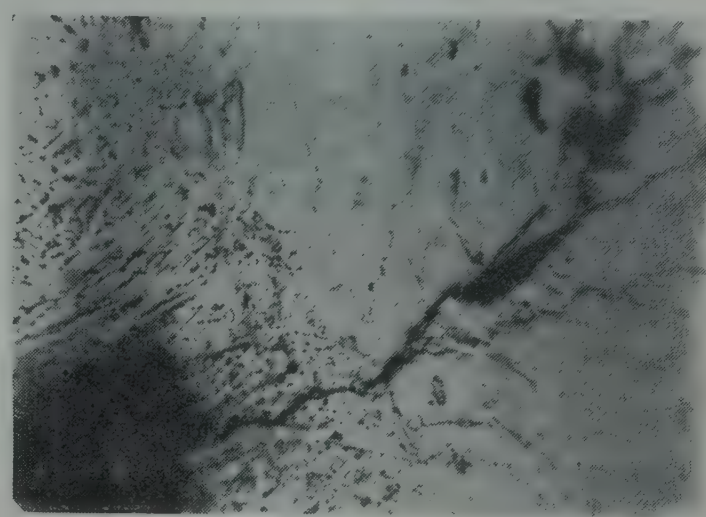


Photo 7
Cracking Pattern at the Junction of the Weld Metal (Double Weld) ($\times 200$).

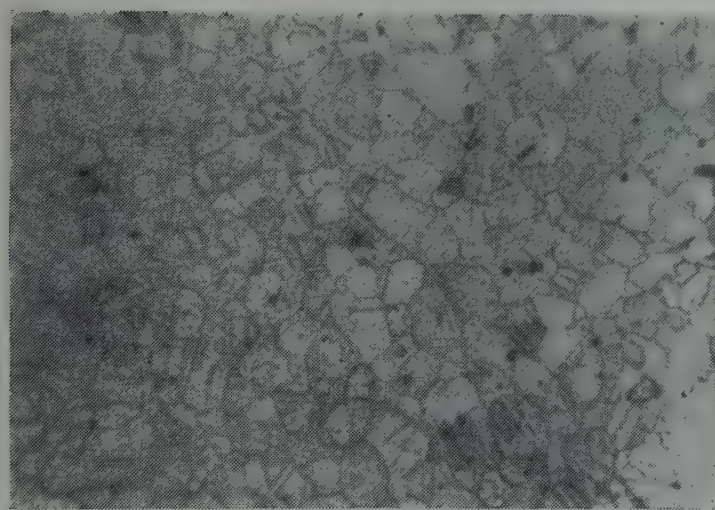


Photo 5
304 Stainless Steel Shell Plate by the Side of Double Weld on the Backing Ring ($\times 115$).

highly branched nature and has its path along the dendrites. Carbide segregation is interdendritic; (c) *Backing Ring* (Photos 8-9): The structure is austenitic with pinholes. The grains appear to be plastically strained. There is complete absence of sigma phase. Typical transgranular cracking is observed, the cracks being highly branched. Carbide segregation has been observed throughout but it is more prominent along the path of the cracks.

Discussion

The weld zones of samples 3 and 5 have dendritic structure with interdendritic segregation of carbide whereas the parent material has an austenitic structure. This indicates that the welding was of such a nature that post-welding heat treatment was necessary. The interdendritic segregation could have been caused by a

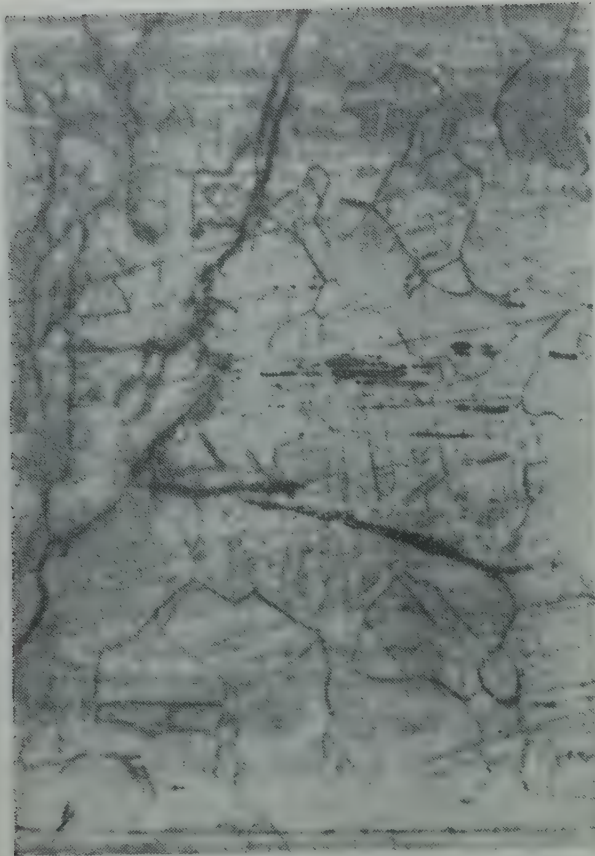


Photo 8

Highly Branched Transgranular Cracks in the 304 Stainless Steel Parent Metal Adjacent to the Double Weld on Backing Ring ($\times 115$).



Photo 9

Highly Branched Transgranular Cracks in the 304 Stainless Steel Parent Metal Adjacent to the Double Weld on the Backing Ring ($\times 270$).

high heat input during welding thin sheets on comparatively thick backing rings, the subsequent slow cooling rate having activated the precipitation of carbide.

Transgranular cracking of backing rings and of parent material adjacent to double weld seams are typical of chloride stress-corrosion. The entire area in the vicinity of the weld had become plastically strained by thermal stresses. The presence of chloride in the scrapings from inside the column because of improper washing of flux material left over after brazing suggests that the causes of cracking were residual stresses after welding and action of chloride. The fact that there were no cracks near the single weld seams suggests that the double welding process with such a narrow gap between the parallel weld seams led to development of stresses of such higher level that the weld material as well as

material adjacent to it became susceptible to stress-corrosion cracking. Moreover, because of carbide segregation in the weld as well as in the parent material, the material became more susceptible to corrosive attack and in presence of high chloride and residual stresses developed hair-line highly branched cracks. Only when these cracks penetrated to some depth, they were located during pneumatic testing. This would explain why the cracks in sample 2, which are much less branched, could not be detected during pressure testing.

Acknowledgement

The authors wish to thank Dr. K. R. Chakravorty, General Manager, for his interest in this work.

NOTE:

Original photo	1	measuring	$4'' \times 2\frac{7}{8}''$	is reduced to	$3'' \times 2\frac{1}{8}''$	in print
"	2	"	$4'' \times 3''$	"	$3'' \times 2\frac{1}{8}''$	"
"	3	"	$3\frac{7}{8}'' \times 2\frac{7}{8}''$	"	$3'' \times 2\frac{1}{8}''$	"
"	4	"	$3\frac{7}{8}'' \times 2\frac{3}{4}''$	"	$2\frac{15}{16}'' \times 2\frac{1}{8}''$	"
"	5	"	$4\frac{1}{4}'' \times 3''$	"	$3'' \times 2\frac{1}{8}''$	"
"	6	"	$3\frac{5}{8}'' \times 2\frac{5}{8}''$	"	$3'' \times 2\frac{1}{8}''$	"
"	7	"	$4\frac{1}{4}'' \times 3''$	"	$3'' \times 2\frac{1}{8}''$	"
"	8	"	$2\frac{3}{4}'' \times 4''$	"	$3\frac{3}{8}'' \times 2\frac{1}{2}''$	"
"	9	"	$4\frac{1}{4}'' \times 3''$	"	$3\frac{7}{8}'' \times 2\frac{1}{2}''$	"

Selective Extraction of Potassium from Bitterns and Mixed Salt Solution by Mexan in Sea Water

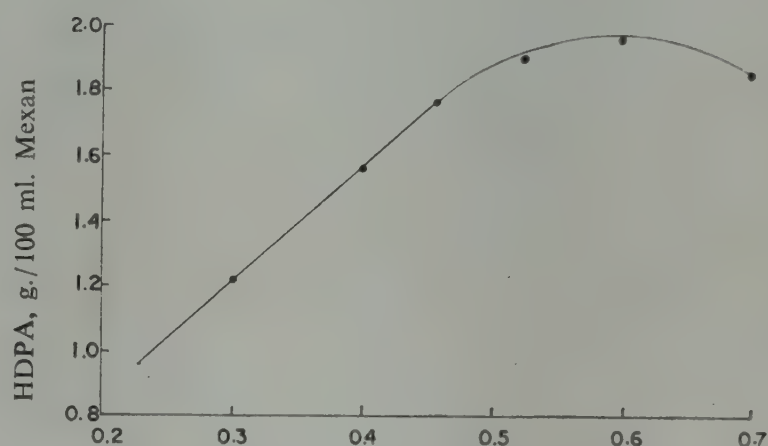
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Magnesium dipicrylamine of sufficient strength could be prepared in sea water and the solution so prepared was found suitable for the selective extraction of potassium from bitterns and mixed salt solution.

In our earlier paper¹ on the selective extraction of potassium from sea water by magnesium dipicrylamine (mexan) solution, the use of pure water for the preparation of mexan solution was one of the limitations considered for the process especially in the coastal regions. It was later on thought that this limitation could be overcome if a solution of magnesium dipicrylamine of sufficient strength could be prepared in the sea water itself. Accordingly, experiments were carried out and finally a magnesium dipicrylamine solution of a suitable concentration in sea water* was prepared (Fig. 1).

It will be observed from the Fig. 1 that when dipicrylamine and magnesium oxide were taken in stoichiometric quantities i.e. 5 g. dipicrylamine and 0.228 g. of magnesium oxide in 200 ml. of sea water and the mixture stirred continuously for six hours at 50°C, a solution of mexan equivalent to 0.968 g. dipicrylamine 100 ml. was obtained on cooling at 30°C. When the quantity of magnesium oxide was raised twice the stoichiometric requirement, mexan of the concentration 1.755 g. dipicrylamine/100 ml. was obtained. However, mexan of the highest concentration in sea water was found to contain 1.960 g. dipicrylamine/100 ml. at 30°C and was obtained when 5 g. dipicrylamine and 0.60 g. of magne-



MgO Treated with 5 g. HDPA in 200 ml. Sea Water, g.
Fig. 1—Concentration Curve of Mexan in Sea Water
(Reaction Time : 6 Hours)

sium oxide were treated as above in 200 ml. of sea-water. Further increase in ratio of magnesium oxide to dipicrylamine added for the reaction did not show any improvement in the concentration of mexan in sea water. The reagent of this maximum strength (of mexan) was used for the recovery of potassium as potassium dipicrylamine (KDPA) from different bitterns and mixed salt solution. The little amount of potash (as KCl 0.8 g./l.) in sea water was precipitated out as KDPA during preparation of mexan in sea water. A sample of the mexan (in sea water) on acidification precipitated HDPA and the filtrate on testing with sodium cobalti nitrite solution was found to be practically free from potassium.

*Sea Water composition (% by weight): NaCl 2.85, Mg SO₄ 0.22, MgCl₂ 20.36, KCl 0.08, Water 96.49, CaSO₄ and Bromine in traces (artificially prepared).

TABLE 1—RECOVERY OF POTASSIUM AS KDPA BY MEXAN PREPARED IN SEA WATER
(Temp. 28-30°C)

Sl. No.	Source of Potassium	Volume Taken, ml.	Potassium Content, g.	Mexan Added ml.	HDKA/ml. of Mexan, g.	KDPA		HDKA Recovered as KDPA, %
						Obtained, g.	Calculated, g.	
1.	Bittern A	10	0.210	63.7	0.0193	1.2302	1.3357	92.1
2.	Bittern B	10	0.210	63.7	0.0193	1.2315	1.3357	92.2
3.	Bittern C	5	0.245	74.4	0.0193	1.4369	1.5601	92.1
4.	Bittern D	10	0.230	69.8	0.0193	1.3479	1.4636	92.1
5.	Bittern E	10	0.240	72.9	0.0193	1.4125	1.5287	92.4
6.	Bittern F	10	0.249	76.0	0.0193	1.4752	1.5931	92.6
7.	Mixed Salt Soln., 150 g./l.	10	0.270	82.4	0.0193	1.6075	1.7285	93.0

Note: Bitterns A and D Tata from Chemicals Ltd., Mithapur, Okhamandal, Gujarat.
Bitterns B and E from Wadala Salt Works, Bombay.
Bittern C from Kharaghoda Salt Works, Kharaghoda, Gujarat.
Bittern F from Bhavnagar Salt Works, Bhavnagar, Gujarat.
For Complete composition of bitterns see Reference 1.

TABLE 2—EFFECT OF VARIATION OF pH OF BITTERNS ON RECOVERY OF KDPA WITH MEXAN PREPARED IN SEA WATER
(Temp. 28-30°C)

Sl. No.	Source of Potassium	Volume Taken, ml.	Mexan Added, ml.	pH of Mexan	pH of Bitterns	pH of Mixture	KDPA		HDKA Recovered as KDPA, %
							Obtained, g.	Calculated g.	
1.	Bittern A	(i) 20	120.8	8.5	6.6	7.6	2.4783	2.6888	92.2
		(ii) 20	120.8	8.5	8.0	8.3	2.4649	2.6888	91.7
		(iii) 20	120.8	8.5	8.5	8.5	2.4568	2.6888	91.4
2.	Bittern B	(i) 20	120.8	8.5	6.5	7.8	2.4783	2.6888	91.2
		(ii) 20	120.8	8.5	8.0	8.3	2.4622	2.6888	91.6
		(iii) 20	120.8	8.5	8.5	8.5	2.4595	2.6888	91.5
3.	Bittern C	(i) 10	150.3	8.5	6.4	7.9	2.8892	3.1370	92.1
		(ii) 10	150.3	8.5	7.9	8.3	2.8766	3.1370	91.7
		(iii) 10	150.3	8.5	8.5	8.5	2.8703	3.1370	91.5
4.	Bittern D	(i) 20	141.1	8.5	6.4	7.7	2.7123	2.9450	92.1
		(ii) 20	141.1	8.5	7.8	8.3	2.7035	2.9450	91.8
		(iii) 20	141.1	8.5	8.5	8.5	2.6917	2.9450	91.4
5.	Bittern E	(i) 20	147.3	8.5	6.4	7.7	2.8394	3.0730	92.4
		(ii) 20	147.3	8.5	7.8	8.4	2.8179	3.0730	91.7
		(iii) 20	147.3	8.5	8.5	8.5	2.8056	3.0730	91.3
6.	Bittern F	(i) 20	152.7	8.5	6.4	7.6	2.9504	3.1862	92.6
		(ii) 20	152.7	8.5	7.8	8.3	2.9281	3.1862	91.9
		(iii) 20	152.7	8.5	8.5	8.5	2.9153	3.1862	91.5
7.	Mixed Salt Soln., 150 g./l.	(i) 20	180.0	8.5	7.0	7.9	3.4968	3.7560	93.1
		(ii) 20	180.0	8.5	7.5	8.4	3.4780	3.7560	92.6
		(iii) 20	180.0	8.5	8.5	8.5	3.4667	3.7560	92.3

Note: HDKA per ml. of Mexan 0.0192 g.

TABLE 3—EFFECT OF TEMPERATURE ON RECOVERY OF KDPA WITH MEXAN PREPARED IN SEA WATER

Sl. No.	Source of Potassium	Volume Taken, ml.	Mexan Added, ml.	HDPA/ml. of Mexan, g.	Temp. of Reaction Mixture, °C	KDPA		HDPA Recovered as KDPA, %
						Obtained, g.	Calculated, g.	
1. Bittern A	(i) 20	127.4	0.0193	30	2.4538	2.6614	92.2	
	(ii) 20	127.4		20	2.4591	2.6614	92.4	
	(iii) 20	127.4		10	2.4644	2.6614	92.6	
2. Bittern B	(i) 20	127.4	0.0193	30	2.4538	2.6614	92.2	
	(ii) 20	127.4		20	2.4617	2.6614	92.5	
	(iii) 20	127.4		10	2.4644	2.6614	92.6	
3. Bittern C	(i) 10	148.8	0.0193	30	2.8737	3.1202	92.1	
	(ii) 10	148.8		20	2.8830	3.1202	92.4	
	(iii) 10	148.8		10	2.8862	3.1202	92.5	
4. Bittern D	(i) 20	139.6	0.0193	30	2.6959	2.9272	92.1	
	(ii) 20	139.6		20	2.7018	2.9272	92.3	
	(iii) 20	139.6		10	2.7076	2.9272	92.5	
5. Bittern E	(i) 20	145.8	0.0193	30	2.8250	3.0574	92.4	
	(ii) 20	145.8		20	2.8342	3.0574	92.7	
	(iii) 20	145.8		10	2.8403	3.0574	92.9	
6. Bittern F	(i) 20	152.0	0.0193	30	2.9472	3.1862	92.5	
	(ii) 20	152.0		20	2.9599	3.1862	92.9	
	(iii) 20	152.0		10	2.9663	3.1862	93.1	
7. Mixed Salt Soln., 150 g./l.	(i) 20	164.8	0.0193	30	3.2150	3.4570	93.0	
	(ii) 20	164.8		20	3.2254	3.4570	93.3	
	(iii) 20	164.8		10	3.2322	3.4570	93.5	

Table 1 shows the results of reactions carried out with the reactants i.e. potassium in bitters and mexan added in stoichiometric quantity at room temperature. It will be observed that the yield of KDPA obtained with different bitters varied between 92-93 per cent, which compared favourably with 93.2-94.2 per cent yield of KDPA reported in earlier experiments¹, obtained with mexan solution in distilled water.

The factors governing the reaction kinetics, such as settling time after reaction, pH and temperature were also studied. It was found that the settling time exceeding 2 hours had no appreciable effect on complete precipitation of KDPA. The effect of variation of pH of bitters and mixed salt solution and of temperature on the precipitation of KDPA are given in Tables 2 and 3 respectively. Generally the pH of bitters and mixed salt solution lies between 6 and 7; on raising pH to 8-8.5 a slight decrease in the yield of KDPA

was observed. Similarly, a little increase in the yield of KDPA precipitated at 20 and 10°C was seen which was due to the decrease in the solubility of KDPA at lower temperatures.

The recovery of dipicrylamine from unreacted mexan going out with the bitters after bulk recovery of dipicrylamine by acidulation was limited by its solubility at the particular pH 2-4. The outgoing dipicrylamine in solution was adsorbed by passing the latter through a column of active charcoal and recovering the adsorbed dipicrylamine by elution with acetone. Experiments on this line confirmed the data obtained earlier.¹

The authors wish to thank Dr. K. R. Chakravorty, General Manager, for his interest in this work.

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Occurrence of Clay Minerals in Some Indian Soils and their Distribution in Different Size Ranges

By

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The clay minerals of some Indian soils have been studied by some physical methods after fractionating them into different size fractions. In the black cotton soil, which is montmorillonitic in nature, chlorite and illite are concentrated in its upper fractions while interstratification of montmorillonite with chlorite is observed in its finest fraction. Also, interstratification of mica with vermiculite as well as of illite with montmorillonite is observed in the finest fraction of two other Indian soils, viz. of Ludhiana and Chinsura, which are predominantly illitic. In case of Ludhiana soil, montmorillonite, which is the minor clay constituent, is concentrated in the finer fractions only.

Clay mineral constituents of the soil play a vital role in the adsorption process with fertilizers. For correct application of fertilizer dose to the soil, a knowledge of the presence of both of its major and minor clay minerals and their physico-chemical characteristics is essential. But the concentration of many of their minor minerals is such that they cannot be identified when the bulk samples are analysed¹. Besides, the occurrence of interstratified clay minerals which are supposed to be present in many of the soils in the finest state of their sub-division is still a controversial issue². In order to identify these constituents and study their physical characteristics, a separation of these constituents from the bulk samples is necessary. A partial separation of different minerals is possible by sedimentation and centrifuging of their dispersed suspension. Other methods such as partial coagulation, electrophoresis, complex formation, etc. have also been tried for their separation.³⁻⁵

The mineralogical composition of some of the Indian soils is known⁶ but very little is known about the occurrence and distribution of many of their minor constituents, particularly those present in the finest state of subdivision. Considering this, an attempt has been made in the present investigation to study the clay minerals of a few samples of Indian soil after separating them into fractions of several size ranges.

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Experimental

The following samples were taken for this investigation: (a) Black cotton soil (from Maharashtra), (b) Ludhiana soil (from Punjab) and (c) Chinsura soil (from W. Bengal). The samples were first sieved through 80 mesh (B.S.S.) to remove roots and coarse particles. Organic matter was separated by extraction with 2 per cent sodium carbonate solution. The procedure for such extraction has been communicated⁷. The sediment, after removing the brown liquid from the samples, was separated in the following different size range fractions by sedimentation and centrifugation of their 2 per cent suspension: (i) 10-2 μ (ii) 2-0.5 μ (iii) 0.5-0.1 μ and (iv) below 0.1 μ size. In case of Chinsura soil, only the last two fractions were taken for this investigation. Fractions upto 0.5 μ size were obtained by gravity sedimentation and the suspension containing particles below 0.5 μ size was fractionated by Sharples' supercentrifuge. The sedimentation and centrifuging of each fraction was repeated several times till the supernatant suspension was almost clear.

The sediment and the suspension were treated with a minimum quantity of hydrochloric acid (dil.) for coagulation and allowed to settle. The coagulated mass was washed 3 to 4 times with distilled water and finally electro-dialyzed.

B.e.c. of each fraction was determined by H-clay-HCl method as adopted by Ganguli.⁸ Oven-dried electro-

dialyzed samples (80°C) were used for the differential thermal analysis; using Linesis DTA instrument. Sample holders were of small platinum cylinders which may be placed over the thermocouple beads. The thermocouples—both for differential and temperature measurement—were made of platinum and platinum/rhodium (13 per cent) wires. The rate of heating was adjusted to about 10°C/mm. by a programme controller. Ignited alumina was used as reference substance. The DTA thermograms are shown in Figs. 1-3. X-ray diffraction patterns of most of the fractions were obtained by a Debye-Scherrer camera (diam. 11.46 cm.) with Ni-filtered Cu K α radiation generated by using 30 Kv. and 20 mA in a Philips PW 1010 unit. Usually 10-12 hours' exposure was given to each sample. The patterns are shown in Fig. 4, whereas B.e.c., differential thermal and x-ray analysis data of these fractions are given in Table 1.

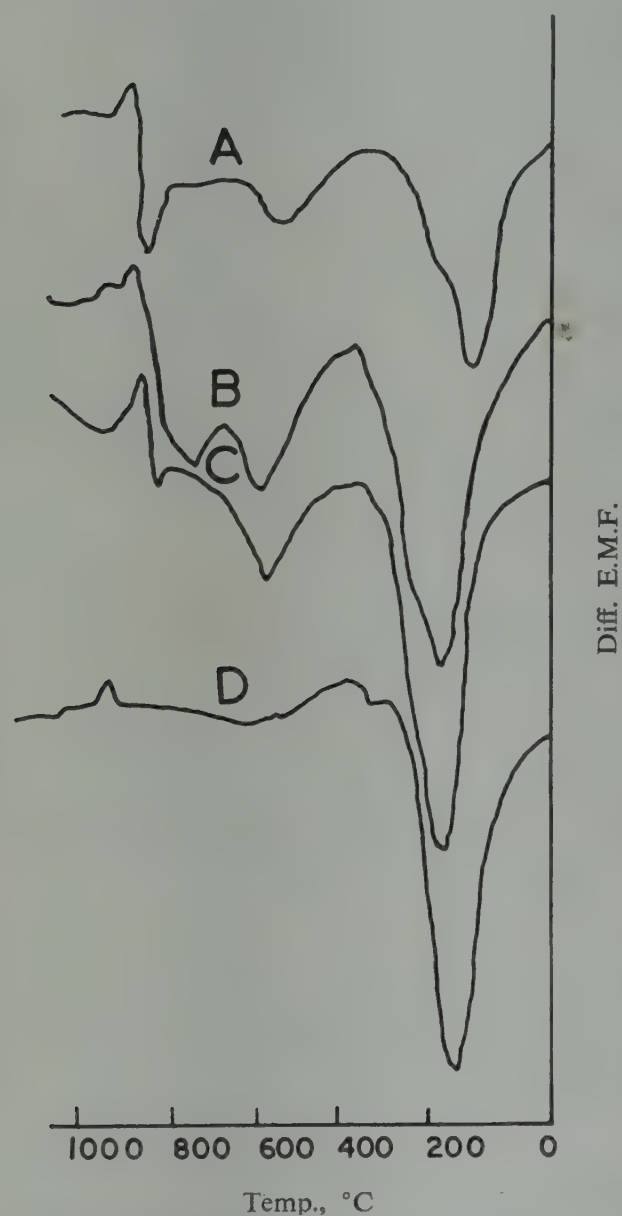


Fig. 1—DTA Thermograms of the Fractions of Black Cotton Soil, A 10–2 μ , B 2–0.5 μ , C 0.5–0.1 μ and D < 0.1 μ size.

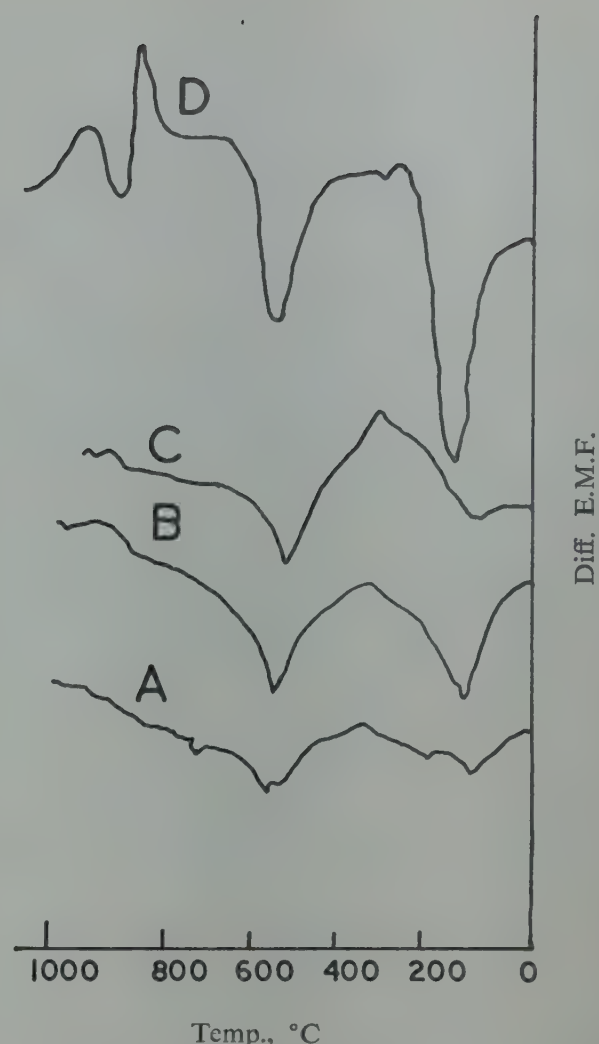


Fig. 2—DTA Thermograms of Ludhiana Soil, A 10–2 μ , B 2–0.5 μ , C 0.5–0.1 μ and D < 0.1 μ size.

Results and Discussion

(a) *Black Cotton Soil*: Montmorillonite was reported to be the clay mineral constituent of this soil⁹. But the DTA thermograms of its fractions upto 0.1 μ are similar to each other whereas that of the finest fraction is different (Fig. 1). Except the initial endothermic peak (Table 1) the thermograms of upper fractions are similar to that of chlorite. Their x-ray patterns (Fig. 4) also indicate lines at 14.75 and 7.08Å (Table 1), which correspond to those of chlorite. Furthermore, the line at 7.08Å disappears when the fractions are treated with warm hydrochloric acid (dil.). Presence of chlorite is, thus, confirmed. The comparatively low B.e.c. value of these fractions (Table 1) is, therefore, due to concentration of chlorite along with other non-clayey minerals. A very weak line at 10.34 Å in their x-ray diffraction patterns (Table 1) indicates that these fractions are also associated with traces of illite. Again, B.e.c. of the finest fraction is high (Table 1) and is comparable to that of montmorillonite, but its DTA thermogram is slightly different from that of the latter. On the contrary, except the peak at 960°C (Table 1) it is similar to that of in-

TABLE 1—B.E.C. DTA & X-RAY DATA OF THE FRACTIONS OF INDIAN SOILS

Fraction	Black Cotton				Ludhiana				Chinsura			
	B.e.c., m.eq/ 100 g.	DTA		Low order X-ray Spacing, d(Å) I	B.e.c., m.eq/ 100 g.	DTA		Low order X-ray Spacing, d(Å) I	B.e.c., m.eq/ 100 g.	DTA		Low order X-ray Spacing, d(Å) I
		Endo	Exo			Endo	Exo			Endo	Exo	
10.2 μ	1.1	150, 550 770, 820	850	—	1.0	100, 190 540, 570 740		9.87 w	—	—	—	—
2-0.5 μ	1.9	160, 580 740	880, 920	14.75 s 10.34 vw 7.08 w	25.6	130, 550	940	14.75 w 10.06 s	—	—	—	—
0.5-0.1 μ	25.0	170, 580 810	850	14.75 s 10.34 vw 7.08 w	51.5	120, 550	930	14.9 w 11.94- 10.27 wb	55.8	150, 550 930	960	—
Below 0.1 μ	113.4	160, 330 560, 610 860	890, 960	14.99- 11.06 wb	66.7	150, 300 570, 780 900	960	15.64 w 11.75- 10.27 mb	81.4	150, 570 960, 900	930	14.6- 10.1 mb

d-interlayer spacing, I-relative intensity, s-strong, m-medium, w-weak, vw-very weak, b-band.

terstratified montmorillonite and chlorite¹⁰. Its x-ray diffraction pattern also shows a broadened basal reflection which is typical of this type of interstratification (Table 1 and Fig. 4).

The initial endothermic peak of the upper fractions and weak exothermic peak at 920-960°C is due to montmorillonite associated in all the fractions of this soil.

(b) *Ludhiana Soil*: This soil is known to be illitic in nature. Other clay mineral reported to be present in soils of Ludhiana region is montmorillonite⁶. In fact, DTA thermogram of its fractions upto 0.1 μ is typical of illite but that of the finest fraction is quite different from the rest (Fig. 2). The peak at 570°C of this fraction is similar to that of illite whereas the other peaks (Table 1) correspond to those of vermiculite. Again, x-ray diffraction patterns (Fig. 4) of the fractions upto 0.5 μ size show a reflection at about 9.87 Å, whereas in case of fractions <0.5 μ this line has been broadened extending from 11.94 to 10.27 Å. Their B.e.c. value is not also as high as that of vermiculite (Table 1.) This shows that the finer fractions may contain mica vermiculite interstratified mineral (hydrobiotite) which is concentrated in the finest fraction. Again, x-ray diffraction patterns of fractions below 2 μ show a reflection at about 14.75 Å in each case. But their DTA thermograms except the finest one do not reveal any characteristic peak due to

vermiculite. The line may, therefore, be ascribed as due to the association of montmorillonite with these.

(c) *Chinsura Soil*: Illite and montmorillonite with traces of kaolinite were reported to be the clay mineral constituents of this soil¹¹. The presence of interstratified illite and montmorillonite mineral has also been reported by Roy et al¹¹ in the fraction below 0.2 μ size from

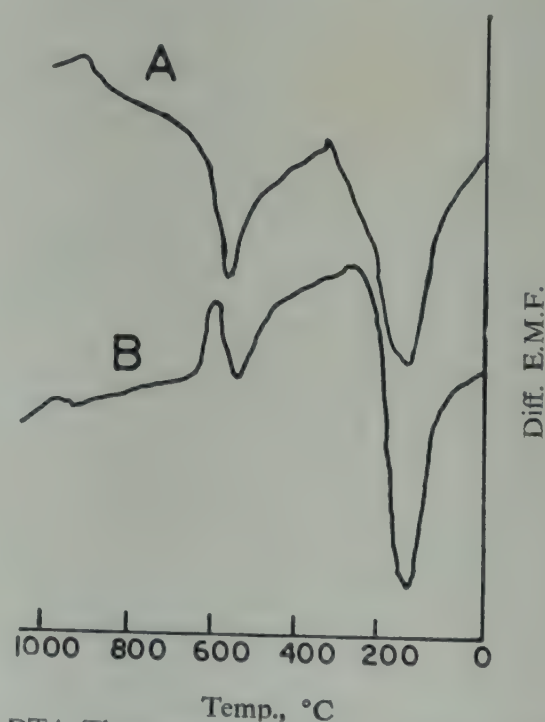


Fig. 3—DTA Thermograms of the Fractions of Chinsura Soil. A 0.5—0.1 μ size, B <0.1 μ size.

x-ray study, but the same could not confirmed by DTA. Results show (Figs. 3 & 4, Table 1) that fractions below 0.5μ size contain this mixed layer mineral which is detectable in the thermogram¹⁰ of the fraction containing particles $<0.1\mu$ size.

Acknowledgements

Thanks are due to Dr. K. R. Chakravorty, General Manager, P & D Division, for his keen interest in this work. Thanks are also due to Dr. B. K. Banerjee, Deputy Superintendent for his encouragement.

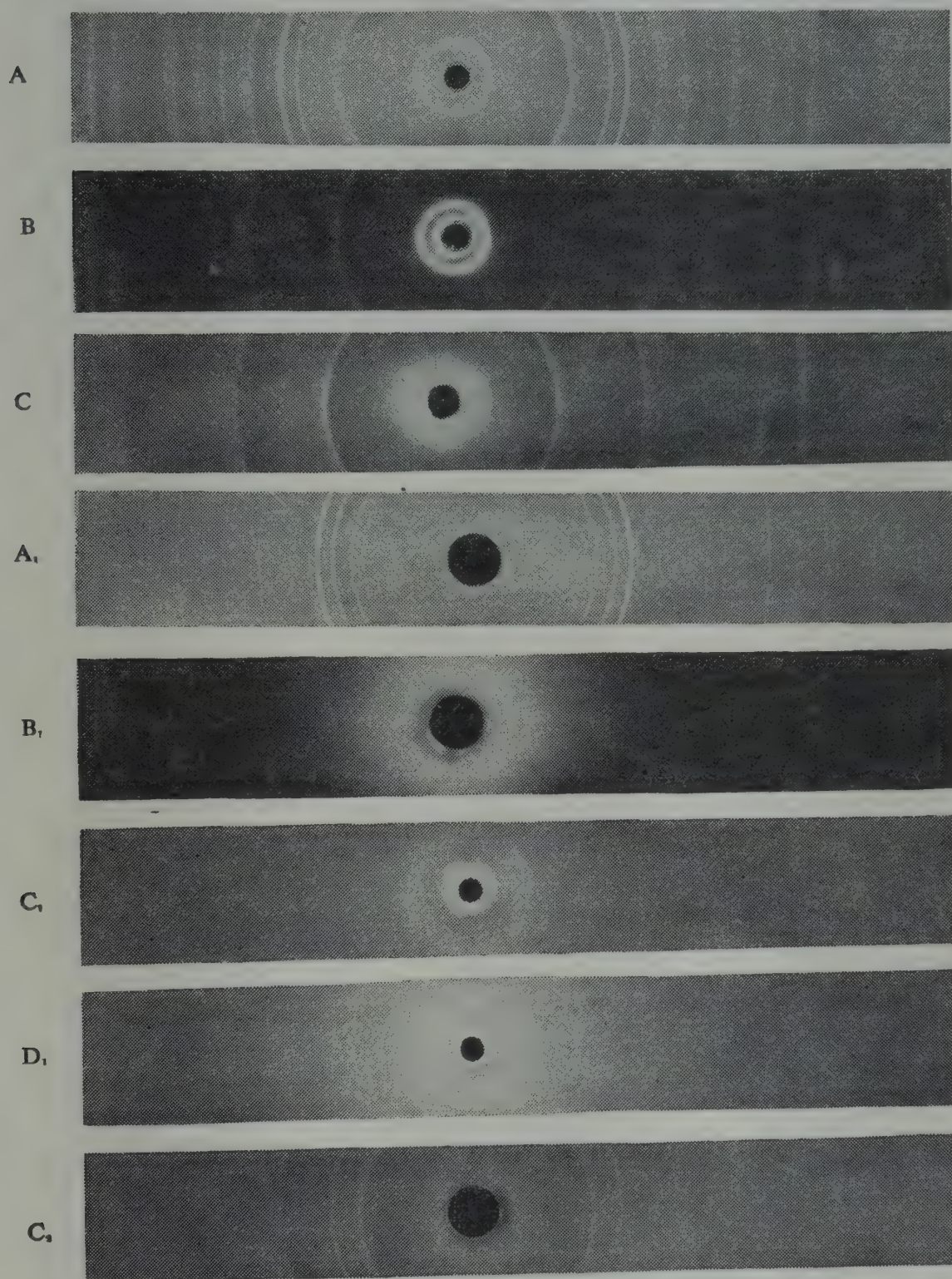


Fig. 4—X-ray Diffraction Patterns of Soil Fractions.

A, B & C—Black Cotton Fractions $2-0.5\mu$, $0.5-0.1\mu$ and $<0.1\mu$ sizes respectively.
A₁, B₁, C₁, D₁—Ludhiana Fractions $10-2\mu$, $2-0.5\mu$, $0.5-0.1\mu$ and $<0.1\mu$ sizes respectively.
C₂—Chinsura Fraction $<0.1\mu$ size.

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Effects of Different Micronutrients on Growth and Yield of Paddy

By

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Six different micronutrients were tried in replicated trials in sandy loam soil at Sindri. They were applied both in soil and as leaf spray. The vegetative growth and yield data were compared. Definite crop yield responses were noticed in case of manganese and zinc applications.

This experiment was undertaken to study the effects of supplementing micronutrients, the deficiencies of which are very much likely due to the constant use of the three major nutrients, viz. nitrogen, phosphorus and potassium. Similar trends were noticed in cases of both *aman* and *boro* paddy, which may be of interest and value to the workers investigating the problems of micronutrient deficiencies in different crops.

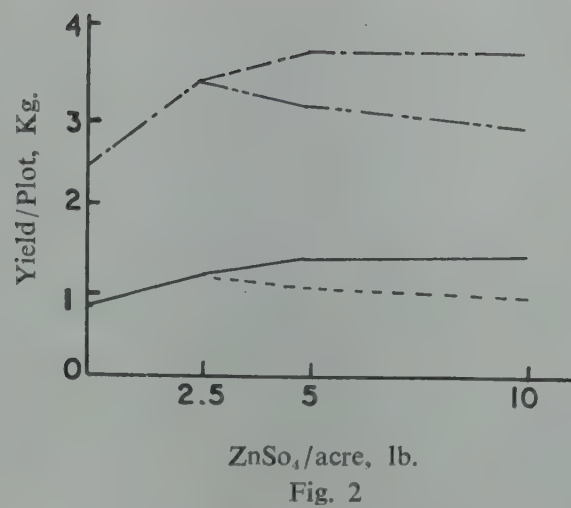
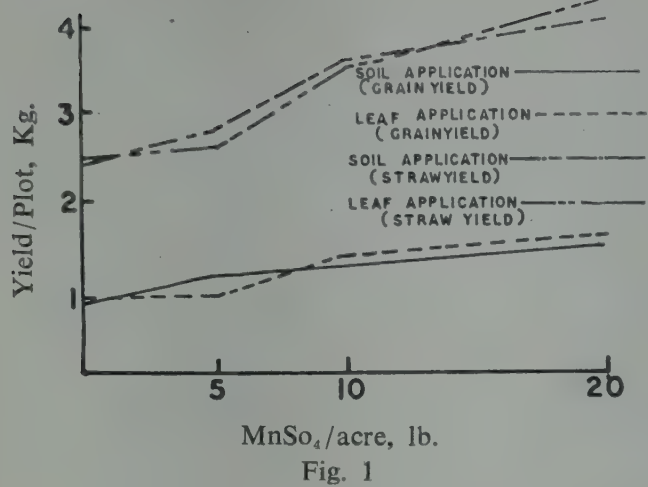
Procedure

Each of *Patnai-23* and *CB-I* varieties of *aman* and *boro* paddy respectively were tried in 4 replicates. Each of the six micronutrients, viz. copper, zinc, boron, manganese, molybdenum and iron in three different levels was applied both in soil and on leaf. The growth measurements, such as rate of increase in height, number of tillers, length of panicles, yield and weight of 1000 grains, were made.

Results

Of the six micronutrients tried, only manganese and zinc showed some definite trends in their responses. The higher levels of manganese-applied plots gave better responses over the lower doses and control in both the cases of soil and leaf applications. In the lower doses of application when manganese was sprayed on leaf, the straw and grain yields of the plots were lower than in the cases of soil application, but as the doses increased their yields superseded those of soil applied ones. These findings may have some relation with the results¹ reported earlier, as they suggest that rice plants can stand a comparatively higher concentration of manganese in body cells.

In the cases of zinc application, the straw and grain yields of the plots receiving lower doses were significantly higher than those of control. As the doses increased, the growth and yield decreased much re-



markedly and abruptly in case of leaf application, but in soil application the rate of increase in growth and yield slowed down and became more or less steady.

The above results have been shown graphically (Figs. 1 & 2).

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Some Observations on Infrared Spectra of Apatites

In connection with the interesting contribution of Chakravorty and Ghosh¹ on infrared spectra of mineral apatites, I would like to report some observations on carbonate and phosphate absorption bands in apatites. I have recently investigated the infrared spectra of mineralogical, synthetic and biological apatites in the light of detailed knowledge of atomic positions provided by x-ray studies. The apatites are structurally very similar (Table 1); however, the symmetric stretching motion varies slightly among the various apatitic systems. The very slight shift in frequencies can be correlated with local structural differences in the vicinity of the (PO₄)⁻³ ion.

TABLE 1—UNIT CELL DIMENSIONS OF APATITES

Sample	a-axis Å	c-axis Å	c/a
Hydroxyapatite	9.42	6.88	0.730
Fluorapatite	9.37	6.88	0.734
Apatite (1.3 % CO ₂)	9.44	6.88	0.728

Some of our results are compared with the work of Chakravorty and Ghosh¹ in Tables 2 and 3

In the region 560-635 cm.⁻¹, Chakravorty and Ghosh¹ observed a band at 628 cm.⁻¹ in hydroxyapatite which they assigned to ν_4 mode of the (PO₄)³⁻ ion. This hydroxyapatite peak at 635 cm.⁻¹ has recently been assigned to the librational mode of the hydroxyl group in hydroxyapatite. This band is found to arise from proton motion due to the shift by $1/\sqrt{2}$ upon deuteration from 635 cm.⁻¹ to 450 cm.⁻¹ The librational motion is basically an oscillatory or hindered motion of the protons². This band at 635 cm.⁻¹ is absent in fluorapatite, chlorapatite, etc., showing thereby that OH⁻ positions have been occupied by F⁻ or Cl⁻ groups. It may be pointed out here that the group theory predicts the presence of three bands for ν_4 (PO₄)³⁻ but only two are observed.²⁻⁸

Chakravorty and Ghosh¹ observed only two bands for (PO₄)³⁻ in fluorapatite and hydroxyapatite. Usually, three bands are observed for hydroxyapatite, fluorapatite, and chlorapatite.^{2,4,5,7,8}

TABLE 2—FREQUENCIES AND ASSIGNMENTS FOR FLUORAPATITE AND HYDROXYAPATITE

Bhatnagar		Chakravorty and Ghosh ¹		Assignment
Fluor-apatite	Hydroxy-apatite	Fluor-apatite	Hydroxy-apatite	
572 } 608 } — }	568 } 605 } — }	575 } 602 } 740 }	563 } 602 } 628 }	ν_4 PO ₄
968	635	—	—	ν_L OH
1045	962	964	959	ν_1 PO ₄
1060	1035	1036	1025	ν_3 PO ₄
1098	1055	1090	1090	
	1095	—	—	

TABLE 3—FREQUENCIES AND ASSIGNMENTS FOR ABSORPTION SPECTRA OF CALCITE AND CARBONATE APATITE

Bhatnagar		Chakravorty and Ghosh ¹		Assignment
Carbonate Apatite	Calcite	Carbonate Apatite	Calcite	
578 } 605 }		563 } 602 }		ν_4 PO ₄
862		872		ν_2 CO ₃
962		959		ν_1 PO ₄
1042 } 1095 }		1026 } 1090 }		ν_3 PO ₄
1430* 1455	1430	1411 } 1462 }	1430	ν_3 CO ₃

*1430 ν_1 symmetric stretch CO₃ in-plane stretch
1455 ν_4 asymmetric stretch

In my opinion Chakravorty and Ghosh¹ concluded incorrectly that D₃ symmetry holds for carbonate ions in carbonate apatite. This they assumed on the basis of (CO₃)²⁻ frequencies observed in their infrared charts. Their statement that carbonate apatite

spectrum compares nearly to that of the calcite also does not appear to be correct.

In the undistorted state, the carbonate ion is planar with three equal, symmetrically placed C-O bonds. Consequently, it belongs to the point group D_{3h} . The free carbonate ion has a fundamental infrared absorption band at 1415 cm^{-1} . The vibration in the ion associated with this band is designated ν_3 and is doubly degenerate which means that it has two modes. Only one absorption band is observed in the undistorted or free carbonate ion as these two modes have the same frequency. If the carbonate ion occupies a position in the crystal whose site symmetry is less than D_{3h} , it will have the symmetry of the site. In the apatite structure, the point group symmetry of the carbonate ion is reduced from D_{3h} to C_{3v} . This lowering of the symmetry causes a separation in frequency of the two modes of ν_3 vibration so that two absorption bands appear between the region $1470\text{--}1410\text{ cm}^{-1}$ (where there was only one before in the free ion). These two bands appear consistently in almost every carbonate apatite structure as shown in Table 4.

TABLE 4— $(\text{CO}_3)^{2-}$ ABSORPTION BAND AT 1415 cm^{-1} IN DIFFERENT SAMPLES

Samples	Frequency, cm^{-1}
Calcite	1430
CaCO_3 + ammonium phosphate	1410}
	1465}
Francolite	1427}
	1453}
Enamel	1410}
	1454}
Dentine	1420}
	1460}
Carbonate apatite	1430}
	1455}

In my opinion Chakravorty et al¹, thus, failed to correlate the splitting of the carbonate band at 1415 cm^{-1} where the apatite structure is present. In calcite, the band near 1430 cm^{-1} appears as a single band due to the C—O asymmetrical stretching. In complicated structures, like carbonate apatite, the carbonate group is distorted and the degeneracy of the mode is lost. It is, thus, clear that compounds with apatite structure do not exhibit the absorption bands characteristic of the carbonate group in calcite. I assume that Chakravorty and Ghosh¹ did not take into account the magnitude of the frequency shifts expected from carbonate ions in different environments.

Acknowledgement

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Notes & News

Production of Ammonium Nitrate and Calcium Nitrate by the Stamicarbon Process

Ammonium nitrate, produced by neutralizing nitric acid of 53 per cent concentration with ammonia at atmospheric pressure or at an increased pressure of 4 atm. has some advantages and disadvantages. In the case of neutralization at atmospheric pressure, the heat of reaction is absorbed in production of steam and is lost; whereas neutralization at increased pressure utilizes the steam (4 atm., 180°C) as heating agent in the first evaporator in which the ammonium nitrate solution is concentrated from 79 to 94 per cent at a pressure of 0.3 atm. A second advantage at increased pressure is a higher enthalpy of the ammonium nitrate solution from the neutralizer. A disadvantage of neutralization at increased pressure is a greater nitrogen loss due to free ammonia in the by-product steam, but this can be offset by passing the steam condensate through a desorption column and recycling the top product to the neutralizer. Concentration of the ammonium nitrate solution to a 99 per cent melt is effected in a second evaporator. For the production of ammonium nitrate prills, this melt is then prilled directly. When calcium nitrate is produced the required quantity of limestone is added prior to prilling.

From a buffer tank on top of the prilling tower, ammonium nitrate or calcium nitrate melt flows into a bucket-shaped container equipped with a scraper which prevents clogging of the prill bucket holes. This fast rotating container distributes the product in fine droplets over the diameter of the prilling tower. The arrangement of prilling equipment ensures optimum effect and maximum capacity. To accelerate the solidification of the droplets of ammonium nitrate melt, air is drawn through the prilling tower of the prills at the bottom of the tower so that temperature of the prills at the bottom of the tower is constant.

The cooled prills are screened and coated

with fine limestone. For pure ammonium nitrate (33.5% N), clay or kisselguhr is preferred as the coating agent. A belt conveyor transports the end product to the storage shed. The two products ammonium nitrate and calcium nitrate are available in the form of prills having a diameter ranging from 1 to 3 mm: the mean diameter is 1.80 mm. Total nitrogen efficiencies are 98 and 97.5 percent. For neutralization at increased pressure, steam consumption requirements are 0.17 and 0.113 tonnes per tonne product respectively.

[*Nitrogen*, No. 46, March/April, (1967), 37]

Urea Plant at Neyveli

The fertilizer plant at Neyveli is designed to produce annually 152,000 tons of urea in the prilled form with a fixed nitrogen content of 70,000 tons. It consumes annually 277,200 MWh of power, 200 crores gal. of water and about 0.8 million tons of raw lignite (including process steam plant).

The raw lignite (with about 56 per cent moisture) is crushed and screened to 0-8 and 8-44 mm. fractions: The 0-8 mm. fraction, after being dried in two Buttner turbine driers to about 8 per cent moisture, is gasified at 1250°C in the fluidized state in three Winkler generators with steam and 98 per cent oxygen. The hot gases at 950°C are taken through waste heat boilers, dust separators and coolers and the dust separated is pneumatically transported to boilers for burning.

The gas from the holder is compressed to about 17 atm. and then purified by the alkazid scrubbing process for removing H₂S, followed by passing it mixed with steam over chromium promoted iron oxide catalyst at 500°C. The converted gas after cooling is freed from traces of sulphur in towers packed with hydrated iron oxide, it is then scrubbed with activated potash (the Vetrocoke process) for carbon dioxide removal, and CO₂ thus removed is stored.

It is finally purified by a caustic soda wash.

The purified gas is dried, precooled in heat exchangers by product gases and then cooled to -40°C by evaporating liquid ammonia. By further cooling with outgoing pure hydrogen-nitrogen mixture, the heavy hydrocarbons, if any, and some methane are liquefied. Cooling to -180°C by boiling nitrogen condenses the methane and a part of the CO and N. The gases are then washed in a fractionating column by liquid nitrogen. The gases from the top of the column are a mixture of pure hydrogen and nitrogen. The additional nitrogen is supplied from the third stage of the nitrogen compressors and the mixture sent to the ammonia plant at 14.5 atm.

The pure H-N mixture is compressed to about 300 atm. and then sent to three ammonia converters containing reduced iron catalyst at 500°C. The ammonia formed is condensed by cooling and the unconverted gases are recirculated back into the converters through ejectors by the help of fresh compressed synthesis gas as feed. The heat of formation is removed by the generation of steam in coils embedded in the converters. The liquid ammonia is stored in two Horton spheres.

The urea plant has a normal capacity of 465 tons/day. The liquid ammonia from the ammonia plant and carbon dioxide from gas purification plant are compressed to 200 atm. and pumped into 4 reactors lined with special alloy steel, where they combined to form urea and water at 180°C. The unconverted ammonia and carbon dioxide are separated from the urea solution after reducing the pressure in 2 stages. The gases are then condensed and scrubbed with water in two stages and the solution of ammonium carbonate obtained is pumped into the reactor along with fresh ammonia and carbon dioxide feed.

The total recycling of unconverted gases as carbamate solution is a new development in urea synthesis technology. The urea solution is further concentrated in evaporators to 99.4 per cent. and the urea

TABLE 1—CONSUMPTION & PRODUCTION DATA FOR UREA PRODUCTION

Consumption		Production	
Material	Quantity/day	Material	Quantity/day
Lignite for Urea Production	1060 tons	Raw Gas (CO + H ₂)	6,85,000 N.cu.m.
Lignite for Steam generation	680 tons	Pure Nitrogen	2,85,000 N.cu.m.
Process Water	40,800 cu.m.	(Oxygen (98%))	208,800 N.cu.m.
Air	1.25 million N cu.m.	Ammonia	285 tonns
Power	840 MWh	Urea (Prilled)	465 tons
		By production power	225 MWh

[Res. & Indus., 12 (1957), 87]

melt is sprayed from the top of two prilling towers. The storage silo is air-conditioned to maintain 60 per cent relative humidity.

Forest Fertilization

Research work on the development of forest by application of different types of fertilizers on trees and their response taking into consideration of economic feasibility is being carried out. Solutions to all problems of forest fertilization have not yet been properly found out and categorical conclusions or recommendations of many factors involved in forest fertilization have not been made.

In a paper presented at forest fertilization symposium at Gainesville, Floride, Mr. B. F. Malac of Woodlands Research Department emphasized on some salient points in forest fertilization. Older trees like slash pine respond to fertilization with greater efficiency. Young, newly established plantations do not have sufficiently developed root systems and consequently, most of the added nutrients are lost either to extraneous vegetation or through leaching.

The economic feasibility of forest fertilization is largely a function of stand density and stand age. The observed response to a given level of fertilization on the part of an individual tree is fairly constant throughout a wide range of stand densities. The most profitable range of stand densities seems to lie somewhere between 200 and 500 stems/acre. Within this range the higher the number of stems/acre the higher the total field/per acre. The influence of age on the economic

advantage of fertilization is obvious: later in the life of the stand additional investments are made the lower the marginal rate of return needs to be to make a profit.

Nitrogen alone appears to be the most limiting factor in forest fertilization. Urea form is more beneficial in the long run than the ammoniacal or nitrate forms of nitrogen. Generally urea seems to be twice as effective as the nitrate salts.

Response to fertilization appears to be strongly affected by the internal drainage of the site. Broadly speaking, twice as much response to similar fertilizer treatments was observed on well to moderate drained sites than on the moderately too poorly drained sites.

[Commercial Fertilizer, 114 (5), 1967, p. 24]

The Stabilization of Ammonium Nitrate Prills

Susceptibility of ammonium nitraet crystals to "phase change" specially through the 90°F transition zone with a 3.6 percent expansion in volume makes it a problem to producers for manufacturing stable ammonium nitrate prills. Many additives are added to ammonium nitrate prills to overcome this problem taking into consideration the influence of factors such as moisture, pH and prilling temperature—which are examined by performing evaluation tests. Investigation shows that among the additives tried, none performed quite as well or as consistently as the magnesium nitrate. For all practical purposes, the

potassium compound showed same promise. But in some brand of potassium nitrate hard prills with less than 10% crushing was found to be contaminated. One of the disadvantages of using soluble salts is their contribution to hygroscopicity. As compared to standard prills, magnesium nitrate prills, when exposed to 81% R. H., absorb 19 times as much moisture in the first hour, six times as much in the next three hours and finally two times as much in 24 to 72 hours. The initial fast rate could be factor in serious caking since moisture between the prill boundaries is evident for the magnesium nitrate prills after three hours. Evidence has already been found that inconsistencies in the experiments with additives were due not only to prill moisture, pH and prilling conditions, but also to solid impurities in both the ammonium nitrate and the additive used. Recognizing the influence of solid impurities on the ammonium nitrate prills, the possibilities of heterogeneous nucleation become evident and by the proper selection of nucleating agents having the desired crystal size and configuration the problem could be overcome.

[Nitrogen, No. 46, March/April (1967), 33]

Fluidized-bed Reaction of Sulphur Oxides with Phosphate Rock

According to the investigation of Hughes and Cameron in 1931 Phosphate rock can be converted to an available (citrate soluble) pyrophosphate form to a maximum extent of 90% at temp. 500-600°C when contacted with SO₃. Phosphate rock can be converted by SO₂ in a water soluble form in presence of air to a maximum extent of about two-thirds at temperature 350-450°C. Regrinding and retreating the reacted rock results in increased conversion. Scheel of Germany developed in 1957 a process for contacting dilute SO₂ gas mixtures with phosphorites above 500°C, obtaining Ca₃(PO₄)₂ and CaSO₄ as products. The most recent investigation is that of Pompowski who obtained best conversion at 700-720°C employing dilute SO₂ gas mixture and a product containing CaSO₄ and Ca₂P₂O₇, or CaHPO₄ depending on whether or not water was present in the gas.

Various experimental works in this line have been carried out and now advantages of using fluidized bed are being explored. In a fluidized bed reactor investigation

carried out showed that gaseous sulphur trioxide is capable of converting about 55% of P_2O_5 to available form within 5 min. in the presence of steam and air, over a wide range of gas mixture composition. The presence of steam is essential, since otherwise the upper limit of conversion is about half that obtained with steam. This indicates that sulphuric acid is the actual reactant. The temperature for obtaining the results described above must be in the range 315-340°C with 325°C the preferred operating point. Above 340°C conversion is sharply reduced, below 315°C fluidization is extremely difficult to maintain.

Sulphur dioxide reaction with phosphate rock is not enhanced by fluidized bed contact. P_2O_5 seems to be converted to polymeric $(P_2O_5)_n$ form. This product is capable of hydrolysis to water soluble form.

[*Sulphur*, No. 70 May/June, (1967), 25]

Methods Used to Increase Capacity of Sulphuric Acid Plants

In contact type sulphuric acid plants several practical modifications have been made to increase the capacity of the plants by 10-50 per cent. These modifications can be readily made involving small expenditure in the capital. The methods which are employed to improve the capacity of the sulphuric acid plants are as follows:

Method No. 1: There is a contact sulphuric acid plant consisting of the following major equipment: process air blowers; air drying tower, sulphur combustion chamber, waste heat boiler, hot-gas dust filter; two, three or four-stage catalytic converter containing several layers of vanadium catalyst pellets; cooling by boilers or steam superheaters between the catalyst stages; sulphur trioxide gas cooler, an economizer and SO_3 absorbing tower, designed to be operated at 30-50% above the nominal capacity, at which level the efficiency of converting sulphur dioxide gas to SO_3 is in the range of 94-90 per cent for SO_2 concentrations in the converter feed gas at 8-9 per cent by volume. The primary limitations to increased capacity of such type of plants is usually the heat-removal equipment located between the catalyst stages in the converter which is not adequate to cool the reaching gas stream from 1100°F to the desired temperature of about 806°F between the catalyst stages and which reduces the SO_2 conversion. To overcome this limitation and to attain greater production capacity

from plants of this design existing hot gas filter is employed as an additional catalytic stage of the converter section. The filter entrapment medium may be removed from the filter shell and replaced by vanadium pellets. The filter may be kept in its original location in the process between the boiler and the converter, but this arrangement requires the addition of new gas cooling equipment to reduce the the gas temperature to 806°F. Von Bree Inc. of U.S.A. have found that it is advantageous in most plants to make changes to the gas duct work so that the filter shell, although not physically moved is relocated between the converter and the SO_3 gas cooler or economizer in the process arrangement. Cooling of the process gas stream to about 806°F between the converter and the filter requires much less heat-transfer surface since the gas temperature reduction is less. The cooling may be accomplished by direct means such as the addition of cool, dry process air or by indirect means such as radiation and convection heat transfer from uninsulated process gas duct work. With this method it has been found possible to increase the maximum production capacity of existing acid plants by 20-50 per cent while also raising the SO_2 conversion efficiency to about 95-97 per cent.

Method No. 2: In the second common type of sulphuric acid plants with air drying tower, process air blower, sulphur furnace, waste heat boiler, hot gas dust filter, heat exchanger, primary converter having one stage of vanadium catalyst with tubes for indirect cooling by atmospheric air between stages, SO_3 gas cooler and SO_3 absorbing tower as major equipment, the heat exchanger serves to cool the process gas. In plants of this design, the primary limitations to more capacity are usually the heat transfer surface in the heat exchanger and in the cooling tubes of the secondary converter.

With the availability of high-purity molten sulphur at the plant site, it is again possible to utilize the hot-gas filter as an additional catalyst stage of the converter section by replacing the filter medium with vanadium catalyst pellets. With this modification, Von Bree Inc have found it most advantageous to retain the filter shell in its same location in the process arrangement; to utilize the existing heat exchanger for cooling the gas between the filter and the primary converter; and to install a new heat exchanger for cooling the process gas between the primary

converter and the secondary converter. The preferred arrangement of the major equipment is then as follows: air drying tower; process air blower; sulphur furnace; waste-heat boiler; hot-gas filter as a converter stage; existing heat exchanger; primary converter; new heat exchanger; secondary converter with existing cooling means between the two stages; SO_3 gas cooler or economizer; and SO_3 absorbing tower. Cooling of the heat exchanger is performed by atmospheric air from a new fan or blower.

With Method No. 2, it has been found possible to increase the maximum production capacity of existing acid plants by 30-40 per cent while also raising the SO_2 conversion efficiency to about 96-98 per cent. This method also permits the concentration of SO_2 in the process feed gas to be raised in order to obtain more capacity in the plant.

Method No. 3: Since many existing acid plants of various designs and arrangements employ fire-tube type waste-heat boilers between the sulphur combustion furnace and the hot-gas filter or the converter, in which the process gas stream is in the range of 2,000°F (1,093°C) to 806°F (430°C). Von Bree have given consideration to the possibility of placing vanadium catalyst pellets inside the boiler tubes in order to convert part of the SO_2 as the feed gas passes over the pellets during the cooling period. Studies of the reaction kinetics of SO_2 oxidation for this arrangement indicated a potential capability to achieve greater capacity without the necessity of additional catalyst stages, especially in cases where the hot-gas filter was not available for employment as an additional stage. The studies revealed that about 15-20% greater production capacity should be attainable at the same or higher conversion efficiency by the proper selection of the catalyst pellet type size and shape for use inside the boiler tubes.

In all the cases of modifications the economies are very favourable.

[*Sulphur*, No. 70, May/June (1967), 23]

Piping Design for Hydrogen Service

Hydrogen piping requires some special protection devices against hydrogen attack, fissuring and hydrogen accumulation in subsurface voids. Failures in the piping system could be minimized by proper selection of welds, casting voids, flange, valves and packing and internal linings. The welds in hydrogen service which are

more susceptible to hydrogen attack should have the same alloy content as the base material and they should be checked periodically. Every effort should be made to obtain high quality root configuration and alignment for welds in high pressure, high temperature hydrogen service. Diffusion of atomic hydrogen into subsurface voids and laminations in steels as a result of high hydrogen pressure may cause blisters and cracks if casting quality is not maintained. Valve castings and cast fittings used in hydrogen service should be inspected 100 per cent radiographically to ensure that they conform to quality specification. The ability of hydrogen to penetrate very small openings and crevices causes problems with flange leakage. Ratings of flanges should be based as pressure and temperature. Flanges with spiral wound or double jacketed asbestos gaskets are useful. Flange that is not absolutely necessary is to be avoided. Weld in valve could be used in place of flanges where necessary. Flanges can be located at points of lowest stress and these points could be detected by computer programs. One of the ways to avoid problems in high temperature service is to insulate individual bolts or place insulation between the gasket seating surface and bolt ring to keep the bolts cooler. The bolts will therefore undergo less thermal expansion and will tend to keep the flange seated under bolt strain. In severe services and particularly as flange sizes increase special procedures are adopted to assure adequate and uniform bolt tightening and gasket seating. For high temperature hydrogen services, valves should be of the flexible disc, split wedge or double disc design to provide tighter shut-off and prevent jamming of the gate if the valve cools down in the closed position. The wedge and body seat should be hard faced to prevent galling. The packing material should be highly inorganic and resistant to hydrogen attack. For high temperatures, a braid over core construction is recommended. The exterior braided jacket should be made of highest quality asbestos with an inconel or monel wire insert. The packing should contain a corrosion inhibitor to prevent steam pitting and should be lubricated and surfaced with dry graphite lubricant. It is also desirable to install grease connections into the valve packing box to stop leakage by injecting into packing glands on the run whenever necessary. Thermal insulation should be put inside the hydrogen line. The effect of certain parameters such as hydrogen partial pressure, temperature, refractory

density and composition, application techniques, refractory cell structure and others have to be evaluated for necessary corrections. Depending on service conditions either a single layer or dual layer lining can be used. The quality of the lined piping system must conform to the rigorous specifications.

[*Hydrocarbon Processing*, 46 (3) (1967), 148]

Phosphoric Acid Manufacture

The present installed capacity of phosphatic fertilizer units in India is 0.2 million tons P_2O_5 . The demand for phosphatic fertilizers is increasing, and it is estimated that by 1970-71 total consumption of phosphorus as P_2O_5 will be about 1.8 million metric tonnes. To meet this demand about 1.8 mt. of sulphur will have to be made available by 1970-71 only for phosphatic fertilizers. Because in India phosphoric acid is manufactured by 'Wet' process where sulphuric acid is used for digesting the rock phosphate and for every ton of P_2O_5 produced about one ton of sulphur is used as sulphuric acid.

As shortage of foreign exchange and unfavourable international situation for procuring sulphur, whether the phosphoric acid can be manufactured by acids other than sulphuric was a problem. In India hydrochloric acid has always been available in surplus as a by-product of caustic soda industry. The difficulty in using HCl for digesting rock phosphate was separation of phosphoric acid from calcium chloride.

By solvent extraction method, Dr. B. S.

Garud of M/s Shriram Fertilizers & Chemicals, New Delhi, claims that the separation is feasible and process has been successfully used in a plant on a commercial scale. Though the disposal of calcium chloride effluent from hydrochloric acid based industry is not yet studied, it is claimed that the overall production cost of phosphoric acid by this method compares very favourably with that of the conventional process.

The process consists of the following steps:

(1) *Dissolution*: The rock phosphate is digested with aqueous hydrochloric acid in agitated digestors. The dissolution liquor is decanted in thickeners and sent for extraction. The sludge from thickeners is pumped to waste.

(2) *Extraction*: The phosphoric acid in dissolution liquor is extracted with organic solvents. The solvents normally used are C_4 and C_5 alcohols. The phosphoric acid passes into the solvent phase and is recovered by extraction from water. The dilute phosphoric acid is pumped to concentration section.

(3) *Concentration*: The aqueous acid is concentrated in a system of multiple effect evaporators. The residual Hydrochloric acid and solvent are separated and recycled. The product acid obtained is 80-95 per cent H_3PO_4 (58-69 per cent P_2O_5) concentration.

(4) *Solvent Recovery*: The spent calcium chloride brine from the extraction operations contains dissolved solvent which is recovered by continuous rectification.

TABLE—COMPARISON OF COST PER TON OF P_2O_5 IN PHOSPHORIC ACID

<i>HCl Based Process</i>		<i>H₂SO₄ Based Process</i>	
Item	Rs./ton P_2O_5	Item	Rs./ton P_2O_5
Rock Phosphate	782	Rock Phosphate	782
HCl	110	H ₂ SO ₄	630
Solvent & Chemicals	47	Utilities	27
Fixed expenses including salaries, depreciation, repairs, maintenance, Insurance, Interest and Overheads, etc.	320	Fixed expenses including salaries, depreciation, repairs, maintenance, Insurance, Interest and Overheads, etc.	160
Total	1389		1599
Or Say	1390		1600

NOTE: 1. No credit has been taken for by-product $CaSO_4$.
2. No provision has been made for disposal of $CaCl_2$.

[*Oil Commentary*, 5(1) (1967), 2]

News in Brief

New Occurrences of Phosphatic Nodules in Chamba District, Himachal Pradesh

Occurrences of phosphatic nodules in phosphate bearing slates have been reported from two localities in Chamba District. The nodule bearing rock is dark, carbonaceous, somewhat graphitic slates which have been tentatively correlated with Infra-Krol. Near the Chakoli bridge, the slates are highly crushed and graphitic. Rich impregnation of pyrite, mostly weathered and malachite-azurite stains are also noticed. In the Dhulan area, the nodules are hard, black or brownish black, rounded pebbles of about 5 cm. across, occurring parallel to the cleavage. A nodule on analysis gave 32.35 per cent P_2O_5 . A specimen of enclosing slate from the same outcrop analysed 3.2 per cent P_2O_5 .

In the Chakoli area, the nodules are rather small measuring 2-3 cm. across. Analysis of the nodule bearing slate from this area is awaited.

The phosphatic content in the nodule from the Dhulan area is of interest and compares well with the nodules from Sirmur district (H.P.) and Mussoorie (U.P.) which analysed respectively at 23.24 per cent and 34.70 per cent P_2O_5 .

[M. N. Sehgal, *Indian Minerals*, 20 (1) (1966), 115]

Preliminary Field Trials with Sulphur Fertilization

Field experiment with sulphur fertilizers was conducted in Norway. Sulphur as powdered gypsum was applied. Powdered pyrites were also included in a series. Turnips, swedes and marrow-stem kale appear to be most liable to sulphur deficiency, and cereals to a lesser extent. The results from sulphate analyses of soil samples from the experimental fields show only small differences in the sulphur content of soil down to a depth of 20 cm. with and without S application even a few months after application of powdered gypsum.

[Forskn. Forsok Landbr., 1966 (17), p. 7.97; Odelien, M. ISMA Bull. de Doc., 1966 (45), p. 101 Abstr. *The World of NPKS*, No. 8, Feb 1967, p. 21]

The Uptake and Release of SO_2 by the Human Nose.

Measurements were made of the absorption and desorption of sulphur dioxide in the upper respiratory tracts of seven healthy men breathing by nose. Virtually all of the inspired sulphur dioxide was absorbed by the nasal mucosa. It was not possible to saturate the system during the period of study at the concentrations used. During expiration sulphur dioxide was desorbed from the nasal mucosa in quantities which totalled approximately 15 per cent of the original concentration inspired. An implication of this study is that chemically minute amounts of sulphur dioxide (less than 1 per cent of the inspired concentration) are, upon reaching the larynx and more distal airways, sufficient to initiate reflex changes in bronchomotor tone.

[Speizer, F. E. and Frank, N. R., *Arch. Env. Health*, 12 (1966), 725]

Use of Cold Absorption Plant in Ammonia Synthesis

The possibility of reducing power expenditure in ammonia production by using a cold absorption plant has been examined at Leuna. With a heat coupling between ammonia synthesis and copper lye wash it is possible, using a cold absorption plant, to cover the entire energy requirement for regeneration and cooling of the copper lye with a proportionally low investment expenditure. The great advantage of this process is that practically no water is required for the cooling process in the cold absorption plant.

[Renker, W., *Chem. Tech.*, 1966, 18, 614]

Production of Non-caking Ammonium Nitrate

Ammonium nitrate was much reduced and the physical properties improved after treating granules in a mixer (of various types) with a charge of the following composition (%): 60-70 screenings from a zinc white plant, containing Zn 10, Fe 10, Al 6, CaO 3, MgO 1, Mn 0.5, NiO 1, Ti 0.01, Mo 0.01, Ag 0.0009, B 0.01, W 0.001, Sn 0.01, Cu 0.4 and 30-40 of the

slurry screening of manganese ore enrichment plant, containing Mn 10-15, Fe 5, Al 5, CaO 8, MgO 10, P_2O_5 5. Trace elements in these screenings are in the citrate-soluble form. 3-5 per cent of the weight of ammonium nitrate is used as charge.

[Ganz S. N., Kuznetsov, I. Ye., et al. *Khim. i tekhnol. mineral'n. udobr. Tashkent, Fan*, 1966, 128; Ref. Zhur. 1966, 23, 1150]

Aerial Sowing and Fertilizer Dressing

A service for aerial sowing of cereals has been undertaken by Soil Fertility Dunns Ltd., in U.K. The system comprises a three man team allocated to each chipmunk aeroplane—one member marks the field with fluorescent disks, one loads the special hopper and broadcasting device and the third operates the aircraft. Application rates vary between 1½ and 2 cwt per acre depending on variety. Sowing height is 30-40 ft. After the cereal is sown, fertilizer is spread in a similar manner at a rate of 2 cwt. per acre. Costs vary between 27 and 30 s. per acre depending on closeness to the suitable depot, nearness of airstrip or suitable field and the number of acres to be sown.

Mass Fertilizer Distribution From the Air for Developing Countries

The problems of distribution of fertilizers in developing countries are as crucial and important as those of convincing the farmer population of the value of fertilizers. It has been suggested to distribute the fertilizers from air which will be of greater practical value.

[*World Crops*, 18 (3) (1966), 22; Abstr. *The World of NPKS*, No. 8, Feb 1967, p. 20]

Manufacture of Potassium Schoenite in Kutch

The great Rann of Kutch, which extends upto Indo-Pakistan boundary in the north-west and covers an area of about 16,780 sq. kilometers, abounds in concentrated sub-soil brines rich in potassium salts. These

brines are suitable for the manufacture of potassium schoenite fertilizer in accordance with the process developed in the Central Salt & Marine Chemicals Research Institute, Bhavnagar.

In a paper, K. K. Bokil, G. T. Gadre & D. S. Datar [*Salt Res. and Indus.*, 4 (1967), 45] have suggested to instal a 10,000 tonnes per annum potassium schoenite plant which will require bittern resulting from the production 3,75,000 tonnes of common salt. The end bittern after the production of mixed salt will be utilized to produce 35,000 tonnes of crystalline magnesium chloride hydrate, for use in the manufacture of (i) pure magnesia of different grades for use as aritacid, in Sorel cement and special magnesia refractories and (ii) hydrochloric acid.

Ammonia Suppresses Oil-burners' Pollution

Oil fuels, even when burnt in well-regulated installations, frequently produce combustion gases containing smuts-small solid particles of incompletely burnt fuel joined together by sulphuric acid derived from the very high sulphur content (often as much as three per cent) of the oil. Pierre Etoe of Societe Francaise des Petroles BP reports the successful elimination of smuts by controlled injection of ammonia gas into the fuel gases. The ammonia neutralizes the acid so that the fine particles cannot coalesce. Measurements of the rate of condensation of acid from flue gas and of its corrosive power were made on a number of industrial oil furnaces, and the effect of various methods of injecting ammonia was investigated. It was found that the most even distribution of ammonia was obtained by first diluting it to one per cent in air, and then introducing the mixture into the flues from multiorificed manifolds. The temperature at the injection point had to be near 100°C and the rate of injection had to be properly controlled to prevent sticky deposits of ammonium bisulphate accumulating. But under the proper conditions, dramatic improvements were realized in all the furnaces modified: the emission of smuts ceased completely and corrosion rates fell to as little as tenth of their previous value. A system is now being applied for treating central heating installations with ammonia solution.

[*New Scientist*, 35 (552) (1967), 27]

Revised Utilities for New Urea Processes

In the urea manufacturing process a new development has been made by SNAM-

Progetti of Italy by which an atmosphere of ammonia rather than carbon dioxide is used to decompose carbamate formed in the urea synthesis loop and it is expected that utilization of this process will be most economic.

In the new process feedstock ammonia and carbon dioxide are passed to a reactor operating either at conventional temperatures and pressures (200-250 atm, 180-190°C) or at lower pressures (120-140 atm.). Unreacted carbamate is separated from the urea solution and is decomposed into ammonia and carbon dioxide in a specially designed vessel. Pressure is maintained at 120-140 atm and, in a single-stage operation, ammonia is passed into the decomposer while a higher-pressure stream of ammonia and carbon dioxide is taken out. Heat from the exothermic decomposition is recovered in a single-stage condenser as low-pressure steam and is utilized in the plant.

SNAM-Progetti considers that single-train units of capacity even greater than 400 t.p.d. could be economically operated with gravity circulation, thereby avoiding the problems of carbamate recycle pumping.

It is estimated that SNAM-Progetti process offers manufacturing costs similar to those of the other recently developed processes.

[*Nitrogen*, No. 48, July/Aug. (1967)]

Adsorption of Nitrogen Oxides From Waste Gas Streams in a Nitric Acid Plant

Experimental studies have shown that a commercial zeolite (molecular sieve) was more efficient than silica gel in removing low concentrations of nitrogen oxides from gas streams. Further studies proved that the zeolite could effectively absorb NO_x from waste gas streams in a nitric acid plant. Adsorbed NO_x was recovered as enriched NO_x and HNO_3 by regenerating the bed at elevated temperatures with hot air and/or steam. A typical recovery pattern was where 74.40% of total output was recovered as HNO_3 of 19.40% acid strength. The balance was recovered as enriched NO_x . About 80-85% of total input was recovered in less than 30 min.

By varying recovery conditions, these investigators state, the recovery could be effected either as enriched NO_x and higher strength HNO_3 or mostly as lower-strength HNO_3 . In either case, there are several places in the nitric acid manufacturing process where either enriched NO_x or

20-25% HNO_3 could be reintroduced, thereby increasing plant production.

L. H. Thompson, in a personal communication to the authors (1966), has estimated that in a 300-ton acid plant, about 4-5 tones p.d. of 60% nitric acid now being wasted could be added to production by feeding back the recovered NO_x into the process stream.

[*Nitrogen*, No. 48, July/August (1967), 38]

Aluminium Tanks for Storage of Nitrogen Solution

A 37% nitrogen solution is stored in the aluminium tanks, each of which is 39 ft high, has 8 ft wide courses and a 50 ft outside diameter. Each tank weighs 61,000 lb and has been fabricated by Pittsburgh-Des-Moines Co. at its Des Moines, Iowa, plant. The light weight of the aluminium has enabled the company to field-erect large shop-fabricated sections, thereby reducing construction time and cost.

Two lines of 8 in. thin-film, epoxy-coated Reynolds Aluminium pipe connect these storage tanks with the company's barge unloading facility on the Illinois River. Part of the 4,850-ft pipeline was laid underground and part above.

Cost of Reynolds Aluminium is claimed to be still lower than for stainless-clad steel. Low maintenance costs only are expected, due to aluminium's ability to resist corrosion.

[*ibid*, 38]

Ammonia for Extraction of Bleached Pulp

Use of ammonia for extraction of bleached pulp, rather than caustic soda, is now economically attractive, according to research workers from the Pulp & Paper Research Institute of Canada (PPRIC). Exposure of chlorinated chemical pulps to a 1-2% mixture of ammonia in steam is stated to give higher yields of pulp without loss of viscosity. The estimated saving is 70 ton in the extraction stage, as a mole of ammonia costs only half as much as a mole of caustic soda. The higher temperature required for ammonia extraction (100°C) is balanced by greater pulp consistency, and as there is less water to be heated the stream costs are equal.

On the laboratory scale, recovery of ammonia is 70-80%. Now PPRIC plans to go to pilot-plant scale, to determine whether the process will be commercially successful.

[*ibid*, 39]

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In the new process feedstock ammonia and carbon dioxide are passed to a reactor operating either at conventional temperatures and pressures (200-250 atm, 180-190°C) or at lower pressures (120-140 atm.). Unreacted carbamate is separated from the urea solution and is decomposed into ammonia and carbon dioxide in a specially designed vessel. Pressure is maintained at 120-140 atm and, in a single-stage operation, ammonia is passed into the decomposer while a higher-pressure stream of ammonia and carbon dioxide is taken out. Heat from the exothermic decomposition is recovered in a single-stage condenser as low-pressure steam and is utilized in the plant.

SNAM-Progetti considers that single-train units of capacity even greater than 400 t.p.d. could be economically operated with gravity circulation, thereby avoiding the problems of carbamate recycle pumping.

It is estimated that SNAM-Progetti process offers manufacturing costs similar to those of the other recently developed processes.

[*Nitrogen*, No. 48, July/Aug. (1967)]

Self-Sufficiency in Fertilizer Plant Technology

A 10-year supplier's credit agreement between Fertilizer Corporation of India and the noted Italian firm, Montecatini Edison, was signed at New Delhi on October 30, 1967 for covering the supply of essential equipment and raw material to be imported for the Corporation's Barauni Project and Namrup Unit's expansion. On completion, each of these fertilizer plants will have an output of 1000 tons of urea per day and together they will account for 3,00,000 tons of plant nutrient—nitrogen—per year, saving thereby Rs. 36 crores annually. In contrast to the previous projects, these will be built

by the F.C.I. on its own know-how, design and engineering besides using its own indigenously developed and produced catalysts. The use of FCI's own developed catalysts in these two projects will alone mean a saving approximately of Rs. 65 lakhs annually in foreign exchange, and the complete indigenous design, engineering and the utilization of indigenously developed catalysts will mean for the projects a total saving of Rs. 4 crores of foreign exchange.

The two plants are expected to go on stream before the end of 1970.

[*FCI News*, 6 (1) (1967), 2]

Assistance to Ceylon in Fertilizer Technology

India will assist Ceylon in building its first fertilizer plant at Hapungaskande near Colombo, which is expected to go on stream by 1971. Using petroleum naphtha from a nearby refinery as feedstock, the factory—a 100% government enterprise—will produce 540 tonnes of ammonia or 930 tonnes of urea per day.

[*FCI News*, 6(1) (1967), 7]

Gypsum and Rock Phosphate Mining by F.C.I.

As a result of partition in August 1947 the rich gypsum deposits of Daudkhel, which were meant for use in the Sindri Fertilizer factory, went over to Pakistan. A gypsum development section was, therefore started in 1949 at Sindri which was later shifted to Jodhpur in 1951—for finding and exploiting gypsum deposits. During 1951-56 nearly 235 gypsum deposits containing reserves of over 100 million tonnes were explored of which about 30 m. tonnes were found suitable for Sindri ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ 83-87 per cent). The exploitation was confined only to surface deposits. The departmental mining at Kavas (Rajasthan) was started in January 1952 and despatches started from May 1952. The following deposits were later opened: Uttarlai (in October 1936), Kurla (Dec. 1961) and Sheokar (May 1962).

After the appointment of a Chief Mining Engineer, the working was accelerated. New gypsum deposits were mined in

the Nagaur area in September 1963, the Suratgarh and Jetsar groups were started in September 1965 and the Kaonj-Bharu deposits in September 1966.

The exploration of apatite in Vishakhapatnam, rock phosphate in Rajasthan and U.P. and gypsum deposits in Bhutan was also undertaken. The mining of apatite was started during 1966-67. The Rajasthan Government got Rs. 37,33,061 as royalty on gypsum despatched from the F.C.I.'s mines. FCI is also supervising the despatches of gypsum being purchased from M/s. B. G. L. Jamsar. It is hoped that rock phosphate mining on a moderate scale will start by 1970. Expansion work is going on in Rajasthan, U. P. and Himachal Pradesh for locating rock phosphate deposits.

[*FCI News*, 6 (1) (1967), 5]

Fabrication of Fertilizer Plants

The following are the projects in India assigned for manufacture of various equipments needed for fertilizer, petrochemical and allied industries: (i) The heavy plate and vessels work at Vishakhapatnam being set up with Czech collaboration having a capacity of 23,000 tonnes per annum including heat exchangers, pipe fabrication, etc. (ii) a second unit more or less on similar lines is being planned with Rumanian collaboration (iii) a part of the requirement of high pressure vessels can be met by the foundry forge plant at Ranchi (iv) valves needed by fertilizer plants can be supplied by Bharat Heavy Electricals at Thiruchirapalli; manufacture of high pressure block valves is also being studied for production with Rumanian collaboration, (v) for pumps and compressors manufacture a project report from Russian collaboration is being scrutinized; (vi) experts have opined that the high pressure centrifugal compressors can be manufactured at the Bharat Heavy Electricals at Hyderabad; (vii) a seamless steel pipe plant is to be established with Rumanian collaboration; Century Rayon is putting up a seamless steel pipe mill of 88,000 tonnes year capacity; (viii) instruments are to be manufactured by two instruments factories—one coming up at Palghat (Kerala) and other at Kota (Rajasthan).

[*Chem. Weekly*, 12 (22) (1967), 4]

STATISTICS

TABLE 1—PRESENT AND PROJECTED WORLD FERTILIZER
NITROGEN PRODUCTION AND CONSUMPTION

'000 tonnes N

	1965-66		1969-70	
	Prod.	Cons.	Prod.	Cons.
Western Europe	6,535	4,848	10,450	6,050
Eastern Europe	3,967	4,107	6,340	6,000
Africa	228	529	735	820
North America	5,535	5,005	9,480	8,660
Latin America	558	727	1,055	1,200
Asia	3,083	3,754	4,950	5,300
Oceania	34	81	150	150
World	19,940	19,051	33,160	28,180

[Nitrogen, No. 48 July/August (1967), 3]

TABLE 2—SUMMARY OF WORLD NITROGEN PRODUCTION AND CONSUMPTION

Summary	1961-62		1962-63		1963-64		1964-65		1965-66		1966-67	
	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.
Western Europe	5,267	4,195	5,580	4,689	6,230	5,066	6,764	5,323	7,317	5,719	7,817	6,119
Eastern Europe	2,218	2,165	2,548	2,515	3,036	3,103	3,581	3,777	4,472	4,651	5,048	5,127
North America	4,416	4,262	4,989	4,835	5,428	5,403	6,304	6,104	6,961	6,425	7,710	7,240
Central America	59	270	124	294	194	407	224	471	249	469	292	528
South America	204	168	216	200	264	229	284	275	280	274	277	314
Asia	2,054	2,619	2,373	2,971	2,765	3,308	3,071	3,619	3,589	4,282	3,876	4,913
Africa	196	417	231	435	234	537	283	607	292	599	304	639
Australasia	25	52	23	53	23	88	31	89	41	88	61	112
World Total	14,439	14,148	16,084	15,992	18,174	18,141	20,542	20,265	23,201	22,507	25,385	24,992

[Nitrogen, No. 48 July/August (1967), 12]

TABLE 3—SULPHUR REQUIREMENT FOR VARIOUS FERTILIZER PROCESSES COMPARED WITH NITROPHOSPHATES

Process	Sulphur Consumption, tons ^a /ton of P ₂ O ₅
Ammonium Phosphate Sulphate	1.64
Ammonium Phosphate Nitrate	0.94
Ammonium Phosphate Urea	0.94
Ammoniated Superphosphate ^b	0.64
Nitric Phosphate manufactured by the following processes:	
Calcium Precipitated With Sulphuric Acid ^c	0.60
With Phosphoric Acid ^c	0.60
With Potassium Sulphate	0
With Carbon dioxide ^d	0
Calcium Removed	0

^aFor 1:1:x grade ratio

^bPlus ammonium nitrate or urea to give 1:1:x ratio

^cFormulated for 40% phosphate water solubility

^dN; P₂O₅ ratio slightly higher than 1:1

[Farm Chemicals, 130 (5) (1967), 26]

TABLE 4—AVERAGE PRODUCTION COST OF FERTILIZERS IN THE PUBLIC SECTOR PLANTS AND THEIR LANDED PRICES DURING 1966-67

	Cost of Production, Rs./tonne	Average C & F Landed Price, Rs./ton
Ammonium Sulphate	443	474
Urea	510	826
Double Salt	435	518
Calcium Ammonium Nitrate	229	399
Ammonium Phosphate	813	779

Note: The above costs compare favourably with the costs of imported fertilizers except in the case of ammonium phosphate.

(Source: Indian Parliament, Aug. 10, 1967)

[Oil Commentary, 5 (2-4) (1967), 15]

TABLE 5—DISTRIBUTION OF FERTILIZER MATERIALS IN INDIA DURING 1966-67

Material	April 66-March 67	July 66-June 67
1. Ammonium Sulphate	1,583,837	1,386,879
2. Ammonium Sulphate Nitrate	86,805	82,111
3. Urea	596,857	643,458
4. Calcium Ammonium Nitrate:		
(a) (20.5% N)	507,261	520,449
(b) (26.0% N)	75,273	80,683
(c) (22% N)	22,711	22,711
5. Ammonium Chloride	34,787	33,455
6. Chilean Natural Nitrate of Soda	120	17
7. Superphosphate		
(a) (16% P ₂ O ₅)	676,413	697,668
(b) (18% P ₂ O ₅)	4,720	5,998
(c) (18.5% P ₂ O ₅)	14,999	12,630
(d) (19% P ₂ O ₅)	—	250
8. Ammonium Phosphate Sulphate (16-20-0)	76,020	81,826
9. Ammonium Phosphate Sulphate (20-20-0)	194,586	186,051
10. Di-ammonium Phosphate (18-46-0)	161,889	205,812
11. Nitrophosphate (16-13-0)	61,170	70,360
12. N. P. K. Mixture (14-14-14)	—	2,570
13. Muriate of Potash*	177,042	206,465
14. Sulphate of Potash	18,854	18,854
Distribution of N, P ₂ O ₅ and K ₂ O in 1966-67		
N	838,736	830,171
P ₂ O ₅	248,602	274,601
K ₂ O	115,710	133,666

*Provisional

[FAI Inf. Serv. 8 (22) (1967), 8]

TABLE 6—INDEX NUMBER OF PER CAPUT TOTAL AGRICULTURE PRODUCTION IN DIFFERENT COUNTRIES

Region & Country	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965 ¹
France	91	99	106	101	102	99	100	104	117	111	121	117	116	120
Netherlands	101	99	100	105	95	100	105	103	116	111	120	113	112	107
Italy	93	104	96	104	103	100	113	113	105	115	115	108	116	118
U.S.A.	102	100	99	100	99	94	99	99	99	98	97	102	99	98
Argentina	101	97	101	94	107	97	103	95	88	95	97	106	101	90
Burma	104	99	98	97	102	88	101	106	104	105	112	110	115	107
Pakistan	104	99	100	97	101	99	96	100	101	102	99	104	100	101
India	92	101	101	102	103	101	103	104	107	107	104	106	105	97
Israel	87	87	105	101	117	118	120	144	145	151	158	160	178	178
U.A.R.	101	95	102	100	102	107	106	108	111	95	112	111	112	113

¹ Estimated

[Monthly Bull. of Agri. Econ. and Stats., (FAO, Rome), 16 (1967), July-Aug., 20]

TABLE 7—PRODUCTION OF FERTILIZERS & CHEMICALS AND CONSUMPTION OF SOME RAW MATERIALS IN F.C.I.'s SINDRI FACTORY

		1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67
I. Products										
(1) Ammonium Sulphate	tonne	335,420	289,826	305,218	284,326	323,523	307,107	311,233	326,757	314,002
(2) Double Salt	„	1,782	22,552	36,005	55,428	62,229	47,211	47,769	55,255	60,018
(3) Urea	„	907	4,733	10,666	13,634	18,717	18,114	17,945	19,025	18,529
(4) Total Nitrogen in above three End-products	„	71,318	68,905	78,364	80,392	92,729	85,100	86,033	91,737	90,068
(5) Coal Tar	„	13,409.5	12,246.2	10,022	11,508	11,571	11,736	11,617.4	11,963.3	11,691.5
(6) Motor Benzol	l. gross	1378076	982277	1140914	1019577	1142075	982892	1068919	677524	666113
(7) Pure Benzene	l.	1336285	1769788	1579626	1713202	1610817	1532734	1450021	1513466	1396108
(8) Refined Toluol	„	242168	222816	257543	158656	121609	167552	184955	236847	204246
(9) Light Solvent Naphtha	„	133469	102011	66377	101375	103217	112123	86068	139215	117351
(10) Wash Oil	„	—	—	—	—	78063	13254	nil	108453	298873
(11) Road Tar	tonne	—	—	—	—	778.3	74.8	2.83	339.2	1531
(12) Chalk	„	—	—	—	—	478855	453352	437518	461925	459237
I. Raw Materials										
(1) Coking Coal	„	—	305710	290388.9	314417.4	321337.5	319430.5	302149.1	310248.5	331412.9
(2) Gypsum	„	—	500189.2	563902.4	665041.3	687187	648635	630893	667257	665264

Note: The ammonium sulphate plant went into production in Oct. 1951. The production figures (in tonnes) of ammonium sulphate from 1951 to 1958 are as follows: 35341 (1951-52), 222860 (1952-53), 253965 (1953-54), 304798 (1954-55), 331295 (1955-56), 339061 (1956-57), and 337360 (1957-58).

[Annual Statistics, 1966-67, Prod. Stat. Sec., FCI Ltd., Sindri Unit]

TABLE 8—INPUT IN RELATION TO CROP PRODUCTION
IN INDIA DURING 1956-61

Input	Increase, %
Fertilizers	45
Irrigation	27
Improved Seed	13
Double Cropping	10
Land Reclamation	9

[Datta, N.P., *J. Ind. Soc. of Soil Sci.*, **15** (3) (1967), 193]

TABLE 10—COST INDEX OF NITROGENOUS FERTILIZERS

Fertilizer	Relative cost index
1. Ammonia	
(a) Anhydrous	1.00
(b) Aqua	1.03
2. Nitrogen solutions	
(a) Pressure type	1.18
(b) Non-pressure type	1.48
3. Solid bagged fertilizers	1.87 to 2.46

[Datta, N.P., *J. Ind. Soc. of Soil Sci.*, **15** (3) (1967), 198]

TABLE 9—RELATIVE CONTRIBUTION OF DIFFERENT KINDS
OF NITROGENOUS & PHOSPHATIC FERTILIZERS IN
WORLD OUTPUT

Source	Per cent of total	
	1956-57	1961-62
Nitrogen		
Ammonium sulphate	31	24
Ammonium nitrate	27	28
Sodium nitrate	4	3
Calcium nitrate	5	4
Calcium cyanamide	4	2
Urea	4	9
Other forms		
(i) Solid	9	12
(ii) Solution	15	17
Organic materials	1	1
Phosphorus		
Ordinary superphosphate	57	50
Concentrated superphosphate	12	15
Basic slag	16	14
Other products	15	21
(Nitrophosphate, metaphosphate, liquid phosphoric acid, defluorinated phosphate rock, organic materials)		

[Datta, N.P., *J. Ind. Soc. Soil., Sci.*, **15** (3) (1967), 196]

EDITORIAL REPORT FOR 1967

TECHNOLOGY is entering into its fifth year. During such a short span, it has witnessed its papers being abstracted by the authoritative and well-known journals of technically advanced countries like the USA, USSR, UK, Japan, GDR, etc. TECHNOLOGY has now come to such a stage where it is being recognized as one of the important Indian journals relating to fertilizer and allied fields. This achievement was made possible only with the all-sided active help that TECHNOLOGY received from various people—members of Publications Committee are amongst them. Bringing out a flawless scientific and technical journal, no doubt, requires veteran printers and TECHNOLOGY is fortunate enough to be associated with a printer like Eastend Printers, Calcutta.

In keeping the standard of TECHNOLOGY, the Editorial staff cannot forget the contribution of contributors. And to make a full justice to our patrons, every effort is being made to ensure the quality of their papers. One of the steps being taken in this direction is to send papers to renowned Indian and foreign referees who are kind enough to make valuable observations for which TECHNOLOGY is always grateful to them. In most of the papers, subject matter and approach to the problem, according to referees, are found all right but their observation is that the author is generally unfair to himself in its careless presentation. And they emphasize that there is much scope to improve the paper. This, we feel, the authors can achieve by following the hints summarized below from the various referees' comments we have received:

Do It First : (a) Get sufficient data to find correlations, (b) try to use standard abbreviations. Explain them and stick to them throughout your paper, (c) try to condense the paper as far as possible, (d) before writing your paper make a thorough study of similar type of work being carried out elsewhere, (e) number the figures and tables in serial order, (f) use "ibid" and "idem" instead of 'do' in references, (g) quote original as well as abstracted references, (h) ensure that figures discussed in the paper are included in the table, (i) write simple English.

Don't Do It : (a) Contradict the statement, (b) draw abrupt conclusions and base conclusions on limited number of experiments, (c) miss the titles and give incomplete titles, (d) duplicate the data by presenting in tabular form and as well as in figure, (e) make observations based on others' studies (except in exceptional cases).

Pay Attention To : (a) Introductions (which need not be lengthy), (b) units you are using, (c) typed manuscripts for its typographical errors, (d) proper and relevant use of words.

Please Bear In Mind : (a) Minor modification on others' work does not justify its publication as a full paper, (b) more pages do not necessarily reflect on the quality of work, (c) lack of clarity of expression hampers the proper appreciation of the paper, (d) readers prefer to read small, crisp and neat papers.

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